ARMY

PROPOSAL SUBMITTAL

The United States Army Research Office (ARO), reporting to the Army Research Laboratory (ARL) manages the Army's Small Business Technology Transfer (STTR) Program. The following pages list topics that have been approved for the fiscal year 2007 STTR program. Proposals addressing these areas will be accepted for consideration if they are received no later than the closing date and hour of this solicitation.

The Army anticipates funding sufficient to award one or two STTR Phase I contracts to small businesses with their partner research institutions in each topic area. Awards will be made on the basis of technical evaluations using the criteria contained in the solicitation, within the bounds of STTR funds available to the Army. If no proposals within a given area merit support relative to those in other areas, the Army will not award any contracts for that topic. Phase I contracts are limited to a maximum of $100,000 over a period not to exceed six months.

Please Note!

The Army requires that your entire proposal (consisting of Proposal Cover Sheets, the full Technical Proposal, Cost Proposal-using the template provided and Company Commercialization Report) must be submitted electronically through the DoD-wide SBIR/STTR Proposal Submission Website (http://www.dodsbir.net/submission). A hardcopy is NOT required. Hand or electronic signature on the proposal is also NOT required.

The DoD-wide SBIR/STTR Proposal Submission system (available at http://www.dodsbir.net/submission) will lead you through the preparation and submission of your proposal. Refer to section 3.0 at the front of this solicitation for detailed instructions on Phase I proposal format. You must include a Company Commercialization Report as part of each proposal you submit; however, it does not count against the proposal page limit. If you have not updated your commercialization information in the past year, or need to review a copy of your report, visit the DoD SBIR/STTR Proposal Submission site. Please note that improper handling of the Commercialization Report may result in the proposal being substantially delayed and that information provided may have a direct impact on the review of the proposal. Refer to section 3.5d at the front of this solicitation for detailed instructions on the Company Commercialization Report.

If you collaborate with a university, please highlight the research that they are doing and verify that the work is FUNDAMENTAL RESEARCH.

Be reminded that if your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released on the Internet therefore, do not include proprietary or classified information in these sections. DoD will not accept classified proposals for the STTR Program. Note also that the DoD web site contains timely information on firm, award, and abstract data for all DoD SBIR/STTR Phase I and II awards going back several years. This information can be viewed on the DoD SBIR/STTR Awards Search website at www.dodsbir.net/awards.

Based upon progress achieved under a Phase I contract, utilizing the criteria in Section 4.3, a firm may be invited to submit a Phase II proposal (with the exception of Fast Track Phase II proposals – see Section 4.5 of this solicitation). Phase II proposals should be structured as follows: the first 10-12 months (base effort) should be approximately $375,000; the second 10-12 months of funding should also be approximately $375,000. The entire Phase II effort should generally not exceed $750,000. Contract structure for the Phase II contract is at the discretion of the Army's Contracting Officer after negotiations with the small business.

The Army does not issue interim or option funding between STTR phase I and II efforts, but will provide accelerated phase II proposal evaluation and contracting for projects that qualify for fast-track status.

Army STTR Contracts may be fully funded or funded using options or incremental funding.

CONTRACTOR MANPOWER REPORTING (CMR) (Note: Applicable only to U.S. Army issued STTR contracts)

Accounting for Contract Services, otherwise known as Contractor Manpower Reporting (CMR), is a Department of Defense Business Initiative Council (BIC) sponsored program to obtain better visibility of the contractor service workforce. *This reporting requirement applies to all STTR contracts issued by an Army Contracting Office.*

Offerors are instructed to include an estimate for the cost of complying with CMR as part of the cost proposal for Phase I ($100,000 max) and Phase II ($750,000 max), under "CMR Compliance" in Other Direct Costs. This is an estimated total cost (if any) that would be incurred to comply with the CMR requirement. Only proposals that receive an award will be required to deliver CMR reporting, i.e. if the proposal is selected and an award is made, the contract will include a deliverable for CMR.

To date, there has been a wide range of estimated costs for CMR. While most final negotiated costs have been minimal, there appears to be some higher cost estimates that can often be attributed to misunderstanding the requirement. The STTR program desires for the Government to pay a fair and reasonable price. This technical analysis is intended to help determine this fair and reasonable price for CMR as it applies to STTR contracts.

- The Office of the Assistant Secretary of the Army (Manpower & Reserve Affairs) operates and maintains the secure CMR System. The CMR website is located here: https://contractormanpower.army.pentagon.mil/.

- The CMR requirement consists of the following 13 items, which are located within the contract document, the contractor's existing cost accounting system (i.e. estimated direct labor hours, estimated direct labor dollars), or obtained from the contracting officer representative:

  (1) Contracting Office, Contracting Officer, Contracting Officer's Technical Representative;
  (2) Contract number, including task and delivery order number;
  (3) Beginning and ending dates covered by reporting period;
  (4) Contractor name, address, phone number, e-mail address, identity of contractor employee entering data;
  (5) Estimated direct labor hours (including sub-contractors);
  (6) Estimated direct labor dollars paid this reporting period (including sub-contractors);
  (7) Total payments (including sub-contractors);
  (8) Predominant Federal Service Code (FSC) reflecting services provided by contractor (and separate predominant FSC for each sub-contractor if different);
  (9) Estimated data collection cost;
  (10) Organizational title associated with the Unit Identification Code (UIC) for the Army Requiring Activity (The Army Requiring Activity is responsible for providing the contractor with its UIC for the purposes of reporting this information);
  (11) Locations where contractor and sub-contractors perform the work (specified by zip code in the United States and nearest city, country, when in an overseas location, using standardized nomenclature provided on website);
  (12) Presence of deployment or contingency contract language; and
  (13) Number of contractor and sub-contractor employees deployed in theater this reporting period (by country).

- The reporting period will be the period of performance not to exceed 12 months ending September 30 of each government fiscal year and must be reported by 31 October of each calendar year.

- According to the required CMR contract language, the contractor may use a direct XML data transfer to the Contractor Manpower Reporting System database server or fill in the fields on the Government website. The CMR website also has a no-cost CMR XML Converter Tool.

- The CMR FAQ explains that a fair and reasonable price for CMR should not exceed 20 hours per contractor. Please note that this charge is PER CONTRACTOR not PER CONTRACT, for an optional one time set up of the XML schema to upload the data to the server from the contractor's payroll systems automatically. This is not a required technical approach for compliance with this requirement, nor is it likely the most economical for small businesses. If this is the chosen approach, the CMR FAQ goes on to explain that this is a ONE TIME CHARGE, and there should be no direct charge for recurring reporting. This would exclude charging for any future Government contract or to charge against the current STTR contract if the one time set up of XML was previously funded in a prior Government contract.

- Given the small size of our STTR contracts and companies, it is our opinion that the modification of contractor payroll systems for automatic XML data transfer is not in the best interest of the Government. CMR is an annual reporting requirement that can be achieved through multiple means to include manual entry, MS Excel spreadsheet development, or use of the free Government XML converter tool. The annual reporting should take less than a few hours annually by an administrative level employee. Depending on labor rates, we would expect the total annual cost for STTR companies to not exceed $500 annually, or to be included in overhead rates.

Army STTR 07 Topic Index

Army STTR 07 Topic Descriptions

A07-T001 TITLE: Long life, low power, multicell battery

TECHNOLOGY AREAS: Ground/Sea Vehicles, Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop a low-power miniature (coin cell or similar) battery with a 30-plus year operational lifespan that is suitable for battery-backed static random access memory (SRAM) and environmentally friendly with minimal disposal issues.

DESCRIPTION: This effort will focus on identifying new and innovative multi-cell battery technologies suitable for powering battery-backup, low power static random access memories (SRAM). The new multi-cell battery shall be a low power miniature (coin cell or similar) battery with a 30 plus year operational lifespan. The new battery technology shall not incorporate toxic metals like cadmium, lead, mercury, etc. and minimize the amount of hazardous materials. New battery technology shall not be constructed from energetic materials that may be explosive under certain conditions. New battery shall not use radioactive materials. New battery technology shall not use high temperature thermal battery technologies. The goal is to create an environmentally friendly battery with minimal disposal issues. The new battery technology will be suitable for battery-backed SRAM memories and SRAM memories for bitstream keys inside field programmable gate arrays (FPGA).

Current battery technology has focused on extending the life of the battery. An alternate approach would be to combine multiple cells inside a battery. Each cell is initially in an inert state. After activation, a cell will operate as a traditional low power battery-backup for low power SRAM typically used to store FPGA bitstream keys. A low activation energy of less than 1% of each cell’s capacity is desired. The time to activate the cell should be less than 1 hour.

In concept, when a cell is approaching the end-of-life, another cell is activated, effectively extending the life of the multi-cell battery. In a four cell battery, with 5 years of operational life per cell; a 20 year lifetime is possible. Minimum lifetime for each cell, once activated, under an average 0.25/n mW load, is one month (approximately 0.2/n watt-hours) where n is the number of cells ($n >= 1$) inside the battery. The weighting, for evaluating the technical merits of the new and innovative battery technology, will be battery life (2), nontoxic, non-hazardous materials (1), and disposal (1).

PHASE I: Contractor will analyze and design a novel concept battery cell. The new battery technology shall not incorporate hazardous or toxic materials like cadmium, lead, mercury, etc. New battery technology shall not be constructed from energetic materials that may be explosive under certain conditions. New battery shall not use radioactive materials. New battery technology shall not use high temperature thermal battery technologies. The goal is to create an environmentally friendly battery with minimal disposal issues.

While in an inert state, the battery has a shelf life of 25 plus years at 25 degrees Celsius. Nominal operating temperature range with slightly reduced performance: -10 degrees Celsius to +40 degrees Celsius. Operation over the industrial temperature range of -40 to +85 degrees Celsius with reduced performance is desired. Battery operation with reduced performance over part or all of the full military temperature range of -50 degrees Celsius to +125 degrees Celsius will be considered a plus.

Upon activation, a cell will provide power for a battery-backed SRAM memory for 0.1 (lower limit) to 5 plus years at 25 degrees Celsius. The energy for activation should be less than 10 % of each individual cell’s energy capacity with a goal of less than 1 %. Contractor shall perform an accelerated aging test on the cell to determine the shelf life in the inert, inactivated state and the operational lifespan of the cell for a simulated SRAM battery back-up memory.

The requirement for the new battery is to operate over the industrial temperature range of -40 to +85 degrees Celsius. We are also interested in the potential performance of the battery over the full military temperature range of -50 to +125 degrees C. The contractor shall conduct an accelerated aging test over the industrial temperature range of -40 to +85 C. Operation over a wider temperature range up to the full military temperature range of -50 to +125 C will be considered a plus.

Contractor shall provide a report describing accelerated aging test and battery lifespan for current levels of 0.1 to 10 equivalent loads for a SRAM with at least 256 bit memory capacity.

PHASE II: Contractor shall develop a multi-cell battery based on the technologies from Phase I to create a battery with greater than a 25 year operational lifespan powering a battery backed SRAM at 25 degrees Celsius. Contractor shall have an independent verification and validation (IV&V) to validate the batteries performance over the industrial temperature range of -40 to +85 degrees Celsius and for current levels of 0.1 to 10 equivalent loads for a SRAM with at least 256 bit memory capacity. Operation over a wider temperature range up to the full military temperature range of -50 to +125 C will be considered a plus. Contractor shall provide a report on the IV&V.

PHASE III: Contractor shall team with a prime contractor and commercialize the new battery technology. The contractor is encouraged to team with a defense prime contractor and a traditional commercial corporation to market the technology to both military and commercial end users. Contractor shall provide an IV&V report on accelerated aging tests for a production level battery showing mean battery life as a function of temperature over the industrial temperature range of -40 to +85 degrees Celsius and for current levels of 0.1 to 10 equivalent loads for a SRAM with at least 256 bit memory capacity. Operation over a wider temperature range up to the full military temperature range of -50 to +125 degrees Celsius will be considered a plus. Contractor shall have an independent laboratory test the battery to flight safety requirements of the FAA. Contractor shall provide an independent laboratory report on the battery's materials and disposal issues. Contractor shall provide a material safety data sheet on battery family.

REFERENCES:

1. N. Weste, and D. Harris: "CMOS VLSI Design: A Circuits and Systems Perspective," Addison Wesley, 2004. ISBN: 0321149017.

2. R. Kaushik, S. Prasad: "Low Voltage CMOS VLSI Circuit Design," Wiley, 1999, ISBN: 047111488X.

3. D. Linden and T. Reddy: "Handbook of Batteries," McGraw-Hill Companies, 2001, ISBN: 0071359788.

4. University of California: "Researchers create first nanofluidic transistor," http://www.physorg.com/news4815.html.

5. Gillette Company: "Zinc-Air Bulletin," 2004, http://www.duracell.com/oem/Primary/Zinc /Zinc_Air_Tech_Bulletin.pdf.

6. V. Barsukov and F. Beck: "New Promising Electrochemical Systems for Rechargeable Batteries: Proceedings of the NATO Advanced Research Workshop," Springer London, Limited, 1996, ISBN: 0792339487.

7. R. Dell, and D. Rand: "Understanding Batteries," Royal Society of Chemistry, 2001, ISBN: 0854046054.

8. T. Minami, et al.: "Solid State Ionics for Batteries," Springer-Verlag New York, LLC, 2005, ISBN: 4431249745.

9. N. Nguyen and S. Wereley: "Fundamentals and Applications of Microfluidics, Second Edition," Artech House, 2006, ISBN: 1580539726.

10. C. Liu: "Foundations of MEMS," Prentice Hall, 2005, ISBN: 0131472860.

11. N. Maluf and K. Williams: "Introduction to Microelectromechanical Systems Engineering," Artech House, ISBN: 1580535909.

12. Technology Review: "Higher-Capacity Lithium-Ion Batteries" http://www.technologyreview.com/read_article.aspx?id=17017&ch=nanotech , June 2006.

13. J. Walko: "Nanobattery technology could eliminate fire risks," http://www.embedded.com/showArticle.jhtml;jsessionid=TSOLYR5YS2YPMQSNDLRSKH0CJUNN2JVN?articleID=192203405 August 23, 2006.

14. MIT Tech Talk: "Researchers employ virus to build tiny batteries," Vol. 50, No. 23, April 2006, http://web.mit.edu/newsoffice/2006/techtalk50-23.pdf.

15. D. Teeters, et al.: "Nano-battery systems," US Patent 6,586,133, July 2003. http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=6586133.PN.&OS=PN/6586133&RS=PN/6586133

16. Brown University: "Brown University engineers create a better battery – with plastic," http://www.physorg.com/news77371085.html.

KEYWORDS: Electronics, battery, field programmable gate arrays, FPGA, SRAM, micro-electromechanical systems, MEMS, micro-fluidic systems.

A07-T002 TITLE: <u>Software Anti-Tamper for Matrix based Algorithms</u>

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Research objective is to investigate improving software level obfuscation for highly regular matrix based algorithms. A number, of recursive algorithms or adaptive algorithms, consists of an iterative matrix equation W(k+1) = f [W(k)] + other terms where W( ) is a matrix. The highly regular structure makes reverse engineering trivial. Software obfuscation increases the difficulty of reverse engineering software. For matrix equations, there are other options for obfuscation at the algorithm level: similarity transforms, transformations for "sparse" matrix equations, etc. The goal here is to combine iterative matrix equations with clever matrix transformations (possibly time varying transformations) with traditional code obfuscation techniques to improve software anti-tamper for matrix intensive algorithms. Some possible applications for obfuscation at the matrix equation level include: Kalman filtering, least-mean squares (LMS) algorithm, state space control theory, short-term Fourier transform, wavelet signal processing, Gerchberg-Saxton algorithm, and streaming real-time image processing. The contractor is asked to select a matrix intensive algorithm and examine obfuscation at the matrix equation level. Contractor may also select an appropriate function domain(s): time, frequency, time-frequency, space, wavelet, etc.

DESCRIPTION: All U.S. Army Program Executive Offices (PEOs) and Program Managers (PMs) are now charged with executing Army and Department of Defense (DoD) anti-tamper policies in the design and implementation of their systems to afford maximum protection of U.S. technologies, thus providing maximum protection against them being obtained and utilized and/or exploited by foreign adversaries. One area of vulnerability is in the software in a weapons system, where there are many critical technologies that can be compromised. Techniques are now emerging to begin to try to combat this loss of the U.S. technological advantage, but further advances are necessary to provide useful toolsets to the U.S. Army PEOs and PMs for employment in their systems. As AT is a relatively new area of concern, the development of AT techniques is in a somewhat immature state and new ideas are always needed.

The goal of software obfuscation is, through transformations, clever disguise, or restructuring of the program, to make it more difficult to reverse engineer computer software. Army and DoD systems use navigation software where data from several sensors are blended together with a Kalman filter. A Kalman filter is a highly, regular,

recursive matrix equation. The structured nature of a Kalman filter makes software obfuscation more difficult. We would like to investigate the possibility of obfuscation at the algorithm level combined with traditional software obfuscation for anti-tamper. The objective section describes some other possible matrix equations for study.
"No technique is invulnerable or even clearly superior to the others in all circumstances; therefore, a mix of protection techniques allows the defense to capitalize on the strengths of each technique while also masking the shortfalls of other techniques." http://www.stsc.hill.af.mil/crosstalk/2004/11/0411atallah.html.
It should also be noted, that the use of off-the-shelf components in a system can seriously compromise an AT design due to the ready availability of open-source documentation. The effort should therefore focus on denying an adversary access to enough information to begin such a data search. The technologies/techniques developed should inhibit an adversary's exploitation and/or reverse engineering effort to a point where it will require a significant resource investment to compromise, allowing the U.S. time to advance its own technology or otherwise mitigate the loss. As a result, the U.S. Army can continue to maintain a technological edge in support of its warfighters.

PHASE I: Contractor shall select a recursive or iterative matrix intensive algorithm. Some possible algorithms are presented in the objective section. Contractor shall propose algorithm level obfuscation technique(s) for the selected algorithm. Some potential challenges for obfuscating matrix equations include performance degradation, error propagation, algorithm stability, and convergence issues. Series approximations to matrix and integral equations may lead to difficulties with convergence. A series of obfuscated terms may lead to problems with correctly deciding the appropriate point to truncate series terms. Problems with finite numerical precision may cause convergence and stability problems. Obfuscation of near singular matrices may result in additional convergence and stability problems. Other numerical, convergence issues, and algorithm stability issues may also be present.

Contractor shall propose an algorithm level obfuscation technique(s) for a selected matrix intensive algorithm. Contractor shall provide a report discussing the feasibility of matrix equation level obfuscation and address the limitations imposed by performance degradation, error propagation, approximations, convergence and stability. Contractor shall provide an estimate, based on his past software anti-tamper knowledge and experience, of the level of anti-tamper protection provided by the proposed matrix algorithm obfuscation concepts.

PHASE II: Contractor shall develop the concepts from Phase I into a functional prototype. Contractor shall provide a report discussing numerical, convergence, and stability issues for the matrix algorithm obfuscation. Contractor shall describe conditions where the matrix level obfuscation provides good convergence and stability. Contractor shall also describe conditions where convergence and stability are poor. Contractor shall combine matrix level obfuscation with tradition software obfuscation techniques.
Contractor shall demonstrate matrix algorithm obfuscation and software obfuscation running on an embedded computer with an operating system. Contractor shall have an independent verification and validation (IV&V) performed to test the anti-tamper/anti-reverse engineering provided by the matrix algorithm level obfuscation and traditional software obfuscation. Contractor shall provide a detailed IV&V report of the anti-tamper/anti-reverse engineering provided by the matrix algorithm level obfuscation and software obfuscation. Contractor shall provide a detailed report(s) describing functionality of the anti-tamper tool.

PHASE III: Contractor shall develop a production grade matrix algorithm obfuscation and traditional software obfuscation tool. Contractor is encourage to team with a prime contractor to apply the new obfuscation technology to a current production level system. Contractor is encourage to consider a version of the obfuscation tool for Homeland Security applications.
Contractor shall demonstrate matrix algorithm obfuscation and software obfuscation running on an embedded computer with an operating system. Contractor shall have an independent verification and validation (IV&V) performed to test the anti-tamper/anti-reverse engineering provided by the matrix algorithm obfuscation and traditional software obfuscation. Contractor shall provide a detailed IV&V report of the anti-tamper/anti-reverse engineering provided by the matrix algorithm obfuscation and software obfuscation. Contractor shall provide a detailed report(s) describing functionality of anti-tamper tool.

REFERENCES:
1. P. Zarchan, and H. Musoff: "Fundamentals of Kalman Filtering: A Practical Approach," American Institute of Aeronautics & Astronautics, March 2005, ISBN: 1563476940.
2. M. Grewal, and A. P. Andrews: "Kalman Filtering: Theory and Practice Using MATLAB," Wiley, Jan. 2001, ISBN: 0471392545.

3. G. Welch and G. Bishop: "An Introduction to the Kalman Filter," Department of Computer Science, University of North Carolina at Chapel Hill, Chapel Hill, NC, February 2001, http://terra.cs.nps.navy.mil/DistanceEducation/online.siggraph.org/2001/Courses/cd2/courses/51/Papers/kalman_intro.pdf .
4. J. Podesta: "Brief Tutorial on the Kalman Filter," RDEC, Picatinny, Nov. 1994, http://handle.dtic.mil/100.2/ADA286571.
5. S. Haykin: "Least-Mean-Square Adaptive Filters," Wiley, September 2003, ISBN: 0471215708.
6. A. D. Poularikas, and Z. M. Ramadan: "Adaptive Filtering Primer with MATLAB," CRC Press, February 2006, ISBN: 0849370434.
7. S. Qian: "Introduction to Time-Frequency and Wavelet Transforms," Pearson Education, November 2001, ISBN: 0130303607.
8. D. Hill and B. Kolman: "Modern Matrix Algebra," Prentice Hall, 2000, ISBN: 0139488529.
9. D. Poole: "Linear Algebra: A Modern Introduction (with CD-ROM)," Brooks/Cole, February 2005, ISBN: 0534998453.
10. M. J. Atallah, E. D. Bryant, and M. R. Stytz, "A Survey of Anti-Tamper Technologies," Cross Talk, Nov. 2004, http://www.stsc.hill.af.mil/crosstalk/2004/11/0411atallah.html.
11. E. Eilam: "Secrets of Reverse Engineering," Wiley, April 2005, ISBN: 0764574817.
12. L. M. Willis and P. Newcomb (editors): "Reverse Engineering," Springer-Verlag, New York, July 1996, ISBN: 079239756.
13. K. A Ingle: "Reverse Engineering," McGraw-Hill Professional, 1994, ISBN: 0070316937.
14. P. Cerven: "Crackproof Your Software: Protect Your Software Against Crackers," No Starch Press, 2002, ISBN: 1886411794.
15. B. Friedland: "Control System Design: An Introduction to State-Space Methods," Dover Publications, March 2005, ISBN: 0486442780.
16. K. Ogata: "Modern Control Engineering," Prentice Hall Professional Technical Reference, November 2001, ISBN: 0130609072.
17. S. Janardhanan: "Discrete-time Sliding Mode Control," Springer-Verlag, New York, October 2005, ISBN: 3540281401.
18. Wikipedia.org "Short term Fourier transform," http://en.wikipedia.org/wiki/ Short_Term_Fourier_Transform.
19. J. R. Fienup: "Phase retrieval algorithms: a comparison," Applied Optics, Vol. 21, No. 15, pp. 2758-2769, August 1, 1982. http://www.optics.rochester.edu/workgroups/fienup/PUBLICATIONS/AO82_PRComparison.pdf
20. Wikipedia.org: "Gerchberg-Saxton Algorithm," http://en.wikipedia.org/wiki/ Gerchberg_saxton_algorithm.
21. Wikipedia.org: "Singular value decomposition," http://en.wikipedia.org/wiki/ Singular_value_decomposition.
22. Wikipedia.org: "Pseudoinverse," http://en.wikipedia.org/wiki/Pseudoinverse.
23. T. Maggiano: "Phase Retrieval Algorithms and their Applications," University of Arizona-Optical Science Center, http://www.u.arizona.edu/~tlmaggia/Fienup.pdf.

KEYWORDS: Information technology devices, software obfuscation, Kalman filter, least-mean-square, LMS, signal processing, image processing, adaptive filter, matrix algebra, linear algebra, state space, anti-tamper, AT, reverse engineering, anti-reverse engineering, ARE, software protection

A07-T003 TITLE: Modular and Authorable Intelligent Tutoring System for Immersive Scenario-Based Training

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: To develop an intelligent tutoring system that could be linked with multiple immersive scenario-based training systems and could be updated by a person without specialized computer experience. The system would monitor trainee performance, provide targeted instructional feedback, and evaluate how well the trainee performed during a training scenario based on training objectives.

DESCRIPTION: Scenario-based training games are currently being used in the Army for a broad range of training domains (e.g., military tactics, support and stability operations, weapons operation, and language training). The research indicates that effectiveness of these training tools is currently mixed (Beal, 2005; Hays, 2005). One reason why training games may not be living up to the hype is that the "instructor" functions of training environments are not regularly included as part of the system (Hays 2005; Belanich, Mullin, Dressel, 2004; Bloom, 1984). One goal of this project is to develop a modular intelligent tutoring system that could be linked to different Army-based training games in order to provide the needed instructor functionality that is currently lacking in many game-based training systems.

For a modular ITS to work appropriately, it would need to exchange data with multiple scenario-based training platforms. The data coming from the training platform would indicate the state of the scenario and provide a low-level depiction of trainee performance. The ITS would use this data to develop a high-level understanding of trainee performance as compared to a model of the training domain. Data going to the training platform would include data to modify the scenario to meet the instructional need of the trainee, which would include instructional feedback.

For scenario-based training systems to be useful to a rapidly evolving military, they need to be easily authorable to keep up with the ever-changing current operating environment. This flexibility needs to be provided to the instructors who implement these types of training systems so they can adequately match the scenario content with the appropriate training objectives (Ainsworth & Fleming, 2006). Therefore, a second goal of this project is to develop an ITS that can be easily authorable by a typical instructor (i.e., person without highly specialized computer skills).

Intelligent tutors are effective training tools, but usually require skilled personnel to develop the system for a particular training platform. An ITS that can be adapted to work with multiple Army-based training platforms and is easily updateable would offer powerful training options to the military that are currently not available. While scenario-based (game-based) training systems have demonstrated limited effectiveness (Hays. 2005), if they are armed with a robust ITS companion to elicit important lessons and training objectives, these training systems may reach their full potential for training today's Soldiers.

PHASE I: Phase I should determine the feasibility of producing a modular intelligent tutoring system that works with multiple immersive Army scenario-based training systems and covers a range of actions (e.g., speech acts and physical acts). The deliverable for this phase includes a feasibility study with specific recommendations for the system to be developed during the Phase II effort.

PHASE II: In Phase II, the findings of Phase I should be used to develop a working prototype of the system to be assessed by instructors using immersive Army scenario-based training systems. Integration of the ITS with two different scenario-based training platforms would be considered success.

PHASE III: Ownership of a modular intelligent tutor system that can be used by various scenario-based training systems should position the company well for integrating their system into game-based training programs in use by the military, as well as private and public sectors. Because the system is modular, it could be linked with a variety of scenario-based training systems. The system would also find a receptive market in both the training and educational fields, where scenario-based training systems are growing.

REFERENCES:
1. Shaaron Ainsworth & Piers Fleming, Evaluating authoring tools for teachers as instructional designers, Computers in Human Behavior, v. 22, p. 131-148, 2006

2. Scott Beal, Using Games for Training Dismounted Light Infantry Leaders: Emergent Questions and Lessons Learned (ARI Research Report 1841). U.S. Army Research Institute for the Behavioral and Social Sciences: Arlington, VA, September 2005

3. James Belanich, Laura N. Mullin, & J. Douglas Dressel, Symposium on PC-based simulations and gaming for military training (ARI Research Product 2005-01). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences, October 2004

4. Benjamin S. Bloom, The 2 sigma problem: the search for methods of group instruction as effective as one-to-one tutoring. Educational Researcher, v. 13, n. 6, p. 4–16, June-July 1984

5. Robert T. Hays, The effectiveness of instructional games: A literature review and discussion. (Tech Report 2005-004). Naval Air Warfare Center Training Systems Division, Orlando, FL, November 2005

KEYWORDS: intelligent tutoring system, scenario, game-based training, simulation, serious games, authoring, instruction

A07-T004 TITLE: <u>DRIVING WISDOM: Web-based Training for Young Adults to Improve Operator Judgments that Mitigate Crash Risk in Privately Owned Vehicles</u>

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop new transformative technologies to improve driver safety. Analyze and develop a knowledge base of driver judgments that balance moderately risky but common hazards with ongoing, transportation requirements; and evaluate web-based, training methods in order to motivate young adults (moderately experienced drivers aged 20 to 35) to learn and apply this information in their daily driving. The tutoring module will tailor instructional feedback to student responses and personal characteristics.

DESCRIPTION: In recent years, between 110 and 130 Soldiers have died annually because of crashes in privately owned vehicles (POV) (https://crc.army.mil/). Therefore, understanding and improving driver safety remains an important Army objective. Driver safety models theorize that risk assessment is critical to driver safety (Evans, 1991, 1993; Jonah, 1986; Deery 1999; Gregersen & Bjurulf, 1996), and empirical data have demonstrated: (a) differences in risk assessment between novice and experienced drivers (Trankle, Gelau & Metker, 1990), and (b) correlations between risk assessment accuracy and POV crash involvement for experienced drivers (Legree, Heffner, Psotka, Martin & Medsker, 2003; Legree, Martin, Medsker & Gregory, 1999). In these research formulations, risk assessment has been conceptualized to include identification, assessment, and reaction to driving hazards and risks. According to these results, drivers who are more likely to be involved in vehicle crashes are less able to detect driving hazards and assess the risk associated with specific hazards, especially those risks involving internal psychological states (e.g., fatigue, stress, illness) as well as poorly-documented external factors (e.g., surface quality, distracting children). Such drivers are less likely to act to mitigate those risks, even when proficient with the mechanics of driving, as are experienced drivers in the targeted age range.

However, reviews of driver education curricula and traffic safety guidance indicate that training programs typically support risk assessment only poorly, and improvements with most driver-training programs have been limited to very specific behaviors (Mayhew & Simpson, 1995; Mayhew & Simpson, 2002). These programs often focus on the mechanics of driving and may address the importance of physical risks (e.g., icy roads), but seldom deal with risks derived from internal states. In fact, research has not fully documented the many conceptual and inherently subtle hazards that influence a driver's psychological state and are frequently encountered by experienced (rather than novice) drivers between the ages of 20 and 35. Moreover, research has not identified actions that might mitigate the risks associated with these specific hazards. Consequently, driving tutorials could be greatly improved by identifying and teaching this knowledge to populations that are fully versant with the mechanics of driving and capable of responding to physical risks.

This project is intended to address this scientific gap by supporting applied research that:

• Surveys young, experienced drivers (between the ages of 25 and 35) to document frequently encountered driving hazards (including internal states) in sufficient detail to identify actions that proactively avoid or reactively mitigate those risks, while balancing transportation requirements.
• Empirically links expectations regarding those hazards & actions to crash involvement metrics.
• Develops web-based tutorials that effectively teach this knowledge to drivers who are 20 to 35 years old using adaptive simulation technologies, which are commercially available and compliant with the Shareable Content Object Reference Model (SCORM) format.

PHASE I: Phase I should determine the feasibility of using critical incident interviews and resulting surveys to document safety risks that are commonly encountered by young, experienced drivers and identify strategies to mitigate and/or avoid those risks. A variety of inductive procedures, such as Latent Semantic Analyses and

Consensus Based Assessment may be considered to analyze these data. The resultant guidance is intended to be practical, balancing travel requirements while minimizing risk. Concurrent with initial efforts to identify safety risks and related strategies, Phase I will design a SCORM compliant modular tutoring system to provide information to students that:

1. Mitigates all risks that are most likely to be experienced by individual students, particularly those based on their internal states and characteristics.

2. Reinforces learning using simulation technologies that emotionally engage students.

The deliverable for this phase includes a detailed experimental study with specific recommendations for the research to be conducted and a working prototype (based on one external risk and two internal risk factors) of the system to be developed during the Phase II effort.

PHASE II: Phase II should expand on Phase I accomplishments to expand the identified risks and actions, while linking understandings of those risks and actions to crash involvement metrics. Phase II will develop web-based modules to effectively teach this information to the target population using intelligent simulation technologies.

PHASE III: Ownership of a web-based driver tutorial that can be used to train hazard recognition and reduce crash risk should position the company well for integrating their product into applications designed to enhance driver safety. The system is envisioned to find a receptive market in private and public sectors oriented towards improving driver safety in young adult populations. These sectors include other military services, student support services for colleges and universities, and the insurance industry.

REFERENCES:
1. Deery, H. A. (1999). Hazard and risk perception among young novice drivers. Journal of Safety Research, 30, 225-236.

2. Evans, L. (1993). Comments on driver behavior and its role in traffic crashes. Alcohol, Drugs and Driving, 9, 185-195.

3. Evans, L. (1991). Traffic Safety and the Driver. New York, NY: Van Nostrand Reinhold.

4. Gregersen, N. P., & Bjurulf, P. (1996). Young novice drivers: Towards a model of their accident involvement. Accident, Analysis, & Prevention, 28, 229-241.

5. Jonah, B. A. (1986). Accident risk and risk-taking behaviour among young drivers. Accident, Analysis & Prevention, 18, 255-271.

6. Legree, P. J., Heffner, T. S., Psotka, J. Martin, D. E., & Medsker G. J., (2003). Traffic Crash Involvement: Experiential Driving Knowledge and Stressful Contextual Antecedents. Journal of Applied Psychology, 88, 15-26.

7. Legree, P. J., Martin, D. E., Medsker G. J. & Gregory, E. (1999). Tacit Driving Knowledge and Traffic Accident Risk: Safety Implications. (U.S. Army Research Institute Study Note 99-03). Alexandria, VA: U.S. Army Research Institute.

8. Mayhew, D., & Simpson, H. M. (1995). The Role of Driving Experience. Ottawa, Ont.: Traffic Injury Research Foundation of Canada.

9. Mayhew, D., & Simpson, H. M. (2001). The safety value of driver education and prevention. Injury Prevention, 8, 113-118.

10. Trankle, U., Gelau, C., & Metker, T. (1990). Risk perception and age-specific accidents of young drivers. Accident, Analysis & Prevention, 22, 119-125.

KEYWORDS: driver safety, risk assessment, accident and crash risk, game-based training and simulation, web-based instruction, SCORM Compliant

A07-T005 TITLE: Interband Resonant-Tunneling-Diode (I-RTD) Hybrid Terahertz Oscillator

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: To design, build and demonstrate a novel hybrid terahertz (THz) oscillator that utilizes optical-triggering of an interband resonant-tunneling diode (I-RTD) device to achieve record output power performance (e.g., > 3-10 milliwatts) across broad portions of the THz frequency band (e.g., 300-600 GHz) from an all solid-state design operating at room temperature. Military relevant applications of this new source technology include point and remote monitoring for chemical and biological threat agents; standoff imaging of concealed weapons and explosives; ultra-high speed/frequency data processing and communications; and characterization of bio-molecular based devices and systems.

DESCRIPTION: The technological goal of developing a robust and powerful source of controllable electromagnetic radiation within the so-called THz frequency regime (i.e., often defined as the portion of the submillimeter-wavelength electromagnetic (EM) spectrum between approximately 1 millimeter (300 GHz) and 100 micrometers(3 THz)) remains one of the long-standing grand challenges of high frequency electronics. As is well known, the THz regime spans across the frequency domain from RF electronics (where devices primarily utilize transport mechanisms) to photonics (where devices primarily utilize quantum mechanical state transitions) and challenging engineering problems exist in this quasi-optical "gap" where EM wavelength is on the order of component size. Specifically, fundamental physical factors have severely limited the performance (i.e., power and efficiency) of all traditional devices concepts - i.e., in attempts both to extend upward from the millimeter-wave and to extrapolate down from the far infrared. Due to these basic factors, the solid-state electronics capability at THz frequencies remains somewhat limited from a basic signal source and systems perspective. However, while technology limits persist, there has been a great wave of growing scientific interest in THz-related phenomenon, and this includes many military-relevant applications areas - e.g., THz spectroscopic detection, identification and characterization of biological agents and standoff imaging of concealed weapons and explosives.

Indeed, these high priority defense and security applications within the THz regime, along with the unique potential payoffs to the fundamental sciences, previously motivated the U.S. Army Research Program to make significant investments into a number of novel, high-risk, solid-state oscillator concepts. This has subsequently led to an important recent breakthrough where an interband-tunneling mechanism present in staggered-bandgap resonant tunneling diodes (RTDs) has been shown useful for accessing instability processes at the nanoscale [1]. This is important because it allows for the elimination of certain broad-band design requirements (i.e., prevent unwanted low-frequency modes) that had severely limited output power performance within fundamental RTD oscillators. Furthermore, as a direct result of a long-term research investment by the by U.S. Army Research Office, accurate models for describing the electron transport phenomenon within Interband RTDs (I-RTDs) were developed for the first time [2, 3] and this led to comprehensive theoretical studies [4] of a Hybrid I-RTD oscillator that utilized optical-triggering to realize record output power performance (i.e., > 3 milliwatts) over a significant portion of the THz band (i.e., 300-600 GHz). Optimization studies have also been used to show the great promise of alternative types of staggered-bandgap hetero-systems [5, 6] that allow for the design of Hybrid I-RTD oscillators which utilize state-of-the-art laser technology (i.e., 1.55 micrometers) to realize predicted output power performance at room temperature that exceeds all other known types of all solid-state oscillators. This research work has provided a detailed design criterion for the entire hybrid circuit design, along with a practical implementation strategy for integrating the optical triggering and an analysis of the heating induced during large signal operation [7] and motivates the development of a new collaborative effort between small business and fundamental research that can be used to realize a practical demonstration of this important new technological capability.

PHASE I: The Phase I effort should apply new physics-based models towards the specification and conceptual design of a novel I-RTD hybrid oscillator that employs optical-triggering to achieve superior output power performance at THz frequencies. The design and optimization studies should also consider alternative types of staggered-bandgap hetero-systems and determine their potential for performance enhancements. The Phase I studies should also specify experimental methods for indirect testing/measurement of device dynamics and acquire data for critical device and circuit parameters where possible.

PHASE II: The Phase II effort should build and demonstrate a prototype I-RTD hybrid THz oscillator that exhibits state-of-the-art output power performance (e.g., > 3-10 milliwatts) across a significant portion of the THz frequency band. The Phase II effort is expected to include strong contributions from staggered-bandgap hetero-systems materials growth/fabrication, device/circuit design and optimization and oscillator measurment and characterization. The Phase II effort should also document the utility of the new oscillator in one or more military relevant THz applications.

PHASE III: The initial goals of the program are to demonstrate the performance and value of the new THz source in highly military relevant applications - i.e., such as monitoring of chemical and biological agents and standoff imaging of concealed threats. However, this same technology would have relevance to a number of private sector areas – i.e., such as advanced laboratory components for scientific characterization studies and for materials/process monitoring in commerical manufactering. Hence, a Phase III effort is expected that would explore these type or near-term private sector opportunities, and possible the exploration of longer-term opportunities such as short-range /wide-bandgap communications and ultra-fast data processing.

REFERENCES:
1. D. Woolard, W. Zhang, and B. Gelmont, “A Novel Interband-Resonant-Tunneling-Diode (I-RTD) Based High-Frequency Oscillator,” Sol. St. Electr., 9, 257 (2005).
2. B. Gelmont, D. Woolard, W. Zhang and T. Globus, “Electron Transport within Resonant Tunneling Diodes with Staggered-Bandgap Heterostructures,” Sol. St. Electr., 46, 1513 (2002).
3. D. L. Woolard, et. al, “Advanced Theory of Instability in Tunneling Nanostructure,” Chap. 8 in “Terahertz Sensing Technology,” Vol.II (World Scientific, Singapore, 2003).
4. W. Zhang, D. Woolard, E. Brown and B. Gelmont, “A Novel I-RTD Based Optically-Pulsed Hybrid Device for Generaing THz oscillations,” Pro. SPIE Symp. Opt. East, 5995, 59950S (2005).
5. D. Woolard, W. Zhang, E. Brown, B. Gelmont and R. Trew, “An Optically-Triggered I-RTD Hybrid Device for Continuous-Wave Generation of THz Oscillations,” Pro. SPIE Symp.on Defense & Security, 6212, 621207 (2006).
6. W. Zhang, D. Woolard, E. Brown, B. Gelmont and R. Trew, “Design and Optimization of an I-RTD Hybrid THz Oscillator based upon In1-xGaxAs/GaSbyAs1-y Heterostructure Systems,” accepted to the IJHSES (2006).
7. D. Woolard, W. Zhang, E. Brown, B. Gelmont and R. Trew, “An Optically-Triggered I-RTD Hybrid THz Oscillator Design,” accepted to the IJHSES (2006).

KEYWORDS: Interband Tunneling, Resonant Tunneling Diodes, Terahertz Frequency, Oscillator Source

A07-T006 TITLE: <u>Nanostructures for dislocation blocking in infrared detectors</u>

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop innovative nanostructures to block Si substrate associated dislocations from propagating into the active volumes of infrared photon detectors.

DESCRIPTION: Present day semiconductor technology requires that infrared focal plane arrays (IRFPAs) employ read out integrated circuits (ROICs) based on silicon (Si). As such, the growth of HgCdTe or III-V quantum structures on Si substrates offers significant advantages of lattice and thermal matching between the ROIC and the substrate. Si substrates are also of low cost and provide the potential for larger array formats. The main difficulties encountered in the growth of these detectors on Si are the large lattice and thermal mismatch between the materials (~19% for HgCdTe/Si) that gives rise to a high density of defects in the epilayers. Both difficulties have been partially overcome using buffer layers, as evidenced by the significant increase in crystal quality in the last 15 years. However, the defect density in the subsequently grown long wavelength infrared (LWIR) layers still is higher than that of epilayers grown on other substrates which are more expensive and often fragile as in CdZnTe substrates. The strain-induced defects propagate into the epilayers, which significantly reduce the sensitivity of LWIR infrared sensing devices and also create pixel to pixel nonuniformity. As research and development efforts advance, it has become obvious that defects are impeding the progress of IRFPAs with Si substrates.

This solicitation seeks to make use of nanotechnology to lower substrate related dislocation densities and increase uniformity for IRFPAs of interest to the Army. It has been recently noted that strain fields induced by quantum dot buffer layers may be employed to suppress the propagation of dislocations(1,2). It has also been suggested that several layers of quantum dots may be most effective in bending or merging dislocations(3). On the other hand, it is important that the quantum dot buffer layers should not themselves create additional defects(4). Thus, dot composition, dot size, and energy coherence are important parameters to control the strain and suppress the dislocation growth. Uniform quantum dot buffer layers may also improve the spatial uniformity of the remaining dislocations and the subsequent detector array. Other novel nanostructures may also provide the desired dislocation filtering properties(5,6).

PHASE I: Demonstrate a reduction in dislocation density by use of nanostructure buffer layers between Si-based substrates and LWIR infrared detector material. Estimate the yield of low defect layers, the improvement of array photoresponse uniformity compared to other techniques, and assess cost effectiveness.

PHASE II: Optimize the physical conditions necessary for effective suppression of dislocation growth. Fabricate and demonstrate LWIR infrared detectors grown on substrates with nanostructured buffer layers that effectively suppress dislocation propagation.

PHASE III: A large number of commercial applications will benefit from low cost infrared photon detectors to include night surveillance, product control, and system thermal management. This technique should also be useful to interface lasers, light emitting diodes, and Microwave/Millimeter Wave Monolithic Integrated Circuits (MIMIC)to silicon electronics. For this STTR, a Phase III effort should be devoted to developing a manufacturing process for infrared detector arrays with improved uniformity and sensitivity.

REFERENCES:
1. M. Bavencoffe, E. Houdart and C. Priester, “Strained heteroepitaxy on nanomesas: a way toward perfect lateral organization of quantum dots” J. Cryst. Growth 275, 305 (2005)
2. Z. Mi, J. Yang, P. Bhattacharya, P.K.L. Chan and K.P. Pipe, “High performance self-organized InGaAs quantum dot lasers on silicon” J. Vac. Sci. Technol. B 24, 1519 (2006)
3. M. Gutierrez, M. Hopkinson, H.Y. Liu, J.S. Ng, M. Herrera, D. Gonzalez, R. Garcia and R. Beanland, “Strain interactions and defect formation in stacked InGaAs quantum dot and dot-in-well structures,” Physica E 26, 245 (2005)
4. K. Sears, J. Wong-Leung, H.H. Tan and J. Jagadish, “The role of arsine in the self-assembled growth of InAs/GaAs quantum dots by metal organic chemical vapor deposition” J. Appl. Phys. 99, 113503 (2006)
5. Y. Chang, J. Zhao, H. Abad, C.H. Grein, S. Sivananthan, T. Aoki and D.J. Smith, “Performance and reproducibility enhancement of HgCdTe molecular beam epitaxy growth on CdZnTe substrates using interfacial HgTe/CdTe superlattice layers” Appl. Phys. Lett. 86, 131924 (2005);
6. K.M. Kim, Y.J. Park, S.H. Son, S.H. lee, J.I. Lee, J.H. Park and S.-K. Park, “Artificial array of InAs quantum dots on a strain-engineered superlattice” Physica E 24, 148 (2004)

KEYWORDS: nanostructure, quantum dot, silicon substrate, dislocation

A07-T007 TITLE: Efficient and Robust Algorithms for Real-time Video Tracking of Multiple Moving Targets

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop novel computational algorithms for real-time tracking of multiple moving targets. The algorithms need to maintain robust performance in complex urban environments and for tracking nonlinear motions.

DESCRIPTION: Video tracking technologies find applications in surveillance systems, autonomous vehicles, sensor networks, and precision munitions. For example, video surveillance plays a key role in force protection. Video tracking is a desirable targeting approach to terminal homing for smart weapons because of anti-jamming capabilities compared to GPS-based solutions. Key components of video tracking include target detection, track association, and target motion estimation. The major drawback of the approach of traditional Extended Kalman

Filtering (EKF) is its performance degradation for tracking nonlinear motions and for handling non-Gaussian noises under high clutter. Improvements to EKF and various alternative approaches such as particle filtering or multiple-hypothesis tracking algorithms have been proposed to improve the performance and robustness of tracking algorithms, but often at the cost of intensive computation [1-7]. Current video tracking systems may work well in laboratory environments or under benign operational conditions, but perform inadequately under severe conditions with low signal-to-noise-ratio [5-7]. Target detection and track association remain challenging issues under such conditions.

The U.S. Army seeks development of novel video tracking algorithms with improved performance for military applications. The intended application is monitoring surroundings for stationary facilities or patrolling military vehicles such as High Mobility Multipurpose Wheeled Vehicle (HMMWV). Available inputs are visual and/or infrared video streams. Recent advances have lead to algorithms with significant reduction in computation requirements and to new approaches integrating detection with motion estimation [1-5, 8-9], which points to potential improvements of tracking performance. The algorithms developed under this STTR topic must be innovative and need to meet the following requirements. (1) They are computationally efficient and can be implemented for real-time tracking of multiple moving targets. (2) They maintain robust performance in the presence of high clutter, occlusion, dynamic range, illumination variation, orientation changes, and moderate image distortion. (3) They track several types of targets in urban environments including human, civilian vehicles, and military targets that could exhibit highly nonlinear motions. For example, a person of interest may walk, run, or stop. (4) They should be able to track a number of targets of different types simultaneously. No assumption of constant number of targets should be made. It’s anticipated that temporal information should be utilized in order to achieve robustness to mitigate temporary loss of frames or bad frames. The algorithms should deliver satisfactory performance for publicly available representative civilian and military data.

PHASE I: Effort in Phase I may be directed to the development of basic tracking algorithms, analysis of details of issues involved, and development of tools such as quantitative analysis or simulation software for the characterization and testing of the algorithms under simplified scenarios. Quantitative characterization of tracking performance should be obtained. Advantages and disadvantages of the proposed algorithms should be explicitly identified and documented.

PHASE II: Efforts are suggested to focus on improving efficiency and robustness of tracking algorithms. Simulation tools should be expanded to consider practical operation conditions with realistic modeling of urban clutter and nonlinear target motion. Tracking performance should be documented and characterized based on experimental data including publicly available representative civilian and military data.

PHASE III: Phase III will further develop and refine algorithms for commercial and military applications. Dual-use applications include navigation of autonomous systems and security surveillance.

REFERENCES:
1. Chang, C., and R. Ansari, “Kernel particle filter for visual tracking,” IEEE Signal Processing Letters, Vol.12, No.3, pp.242-245, 2005.
2. Zhou, S.K., R. Chellappa, and B. Moghaddam, “Visual tracking and recognition using appearance-adaptive models in particle filters,” IEEE Trans. on Image Processing, Vol.13, No.11, pp.1491-1506, 2004.
3. Latecki, L.J., R. Miezianko, and D. Pokrajac, “Tracking motion objects in infrared videos,” Proc. IEEE Conf. Advanced Video and Signal Based Surveillance, 2005, pp.99-104.
4. Sebe, I.O., S. You, and U. Neumann, “Globally optimum multiple object tracking,” Acquisition, Tracking, and Pointing XIX, Proc. of SPIE, Vol.5810, pp.82-93, 2005.
5. Bar-Shalom, Y., X.R. Li, and T. Kirubarajan, Estimation with Applications to Tracking and Navigation, Wiley, 2001.
6. Philips, M.A., and S.R.F. Sims, “A signal to clutter measure for ATR performance comparison,” Automatic Target Recognition VII, Proc. of SPIE, Vol.3069, pp.74-81, 1997.
7. Bruno, M.G.S., and J.M.F. Moura, “Multiframe detection/tracking in clutter: optimal performance,” IEEE Trans. Aerosp. Electron. Syst., Vol.37, pp.925-946, 2001.
8. Bartesaghi, A., and G. Sapiro, “Tracking of moving objects under severe and total occlusion,” Proc. 2005 Intl Conf. Image Processing (ICIP 2005), Vol.1, pp.249-252, 2005.

9. Vermaak, J., S. Maskell, and M. Briers, “A unifying framework for multi-target tracking and existence,” Proc. 2005 7th Intl. Conf. Info. Fusion (FUSION), pp.250-258, 2005.

KEYWORDS: Target detection, target tracking, filtering, infrared, video tracking, surveillance.

A07-T008 TITLE: Algorithms for Image Content Indexing and Information Retrieval from Unstructured or Semi-structured Complex Database

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: To develop innovative computational algorithms for effective image content indexing and information retrieval that retrieve relevant information from unstructured or semi-structured complex database. The retrieved information should be associated with statistical measures of its relevance.

DESCRIPTION: Human can recognize objects with ease even in complex scenes because of the availability of a massive knowledge base and the ability to efficiently retrieve information from it. Therefore, an alternative approach to automatic target recognition is to create a comprehensive database that contains objects under as many variations of environments and operation conditions as possible, to continuously update the database as new images collected, and efficiently compare observations with objects in the database, all by utilizing increasing computing capabilities. As a first step toward this goal, this STTR topic is aimed at developing effective algorithms for analyzing and indexing image contents from unstructured or semi-structured (e.g., keyword indexed) database with minimum human intervention to reduce false classifications. One potential approach is segmenting objects in an image and indexing the objects based on the contextual information of the image such as scene. Image indexing can be further restricted to defense relevant objects such as military vehicles. Algorithms for information retrieval should allow flexible input formats such as sketches and sample images and must return search results within fraction of a second after searching through a potentially large database created by the outputs of image content analysis and indexing process. Successful retrieval requires intelligent elimination (e.g., through cognitive reasoning) of false positives. The retrieved information should be associated with statistical measures of its relevance.

While text search engines have met with commercial success, the development for image search engines is still in its infancy. Commercial image search engines are limited to keyword search. The main challenges for image indexing and retrieval include (1) lack of low level signatures that can uniquely describe an object of interest, (2) the difficulty of converting low level signatures into high level searchable features, and (3) the wide range of potential variations of such characterizations under different operation environments and conditions when data were collected [1-6]. Over the last decade, a number of testbeds for content-based image retrieval have been established with various aspects of emphasis based on rudimentary features such as color, texture and shape [5-7]. Advances in a few relevant fields (e.g., music information retrieval [4]) also provide knowledge and experience that can be used to aid image retrieval. Recent research suggests that performance can be improved by semantic retrieval [5, 7].

The purpose of this project is to leverage recent progress to advance technologies for military relevant image indexing and information retrieval. The intended application to automatic creation of knowledge base for automatic target recognition systems and decision-making is of critical importance to the Army’s Future Combat Systems.

PHASE I: Phase I may be directed to the analysis and design of algorithms for image content extraction and indexing, and query-based information retrieval. A small-scale computer test should be established. Feasibility study should be performed with documented results to prove that the proposed approach has the potential of success.

PHASE II: Efforts in Phase II are suggested to focus on expanding the scale and scope of the algorithms. Innovative approaches are needed to maintain robust performance for handling large complex unstructured or semi-structured database. Representative examples of publicly available civilian and military data should be processed and added to the database. Potential tasks include (i) demonstration of the capability to analyze content of generic images with minimum human intervention to reduce false classifications, (ii) design of approaches to efficient image-content indexing, and (iii) demonstration of quality of performance for information retrieval with sketch or image query input. A proof of concept prototype system is anticipated.

PHASE III: Phase III military applications include automated creation of target knowledge database for automatic target recognition. Creation of new image indexing systems and launching of the next generation image search engines will have enormous technological impact on both civilian and military sectors with unlimited commercialization potential.

REFERENCES:

1. Berry, M., M. Browne, and J. Dongarra, Understanding Search Engines: Mathematical Modeling and Text Retrieval (2 Ed), Cambridge University Press, 2005.
2. Witten, I.H., A. Moffat, and T.C. Bell, Managing Gigabytes: Compressing and Indexing Documents and Images, Kluwer Academic Publishers, 1994.
3. Grossman, D.A., and O. Frieder, Information Retrieval: Algorithms and Heuristics, Springer, 2004.
4. Special issue on music information retrieval (MIR), IEEE Signal Processing Letters, Vol.13, No.8, 2006.
5. Leow, W., M.S. Lew, T. Chua, W. Ma, L. Chaisorn, and E.M. Bakker (eds.), Image and Video Retrieval, Proc. CIVR 2005, Singapore, July 2005.
6. Lew, M.S. (ed), Principles of Visual Information Retrieval, Springer, 2001.
7. Stix, G., “A farewell to keywords,” Scientific American, Vol.295, No.1, July 2006, pp.91-93.

KEYWORDS: Image indexing, image retrieval, search engine, automatic target recognition, database

A07-T009 TITLE: Frequency-agile monolithic Ka-band filter

TECHNOLOGY AREAS: Electronics

OBJECTIVE: The goal of this research and development is an efficient, light weight and small footprint radio frequency filter that is widely tunable within the Ka band.

DESCRIPTION: Though technology utilizing the Ka band (~26 – 40 GHz) is readily available, applications are constrained by insufficient temperature stability, reliability, size and efficiency. Recent research in the growth of bulk, thin film and nanocomposite active materials has resulted in material systems that respond naturally and efficiently within the Ka band. Some ferroelectric and ferromagnetic materials, for example, are active in the Ka band and can be continuously tuned through applied electric or magnetic fields. Recent breakthroughs have demonstrated that ferroic materials and device structures can be harnessed for frequency-agile monolithic radio-frequency (RF) devices in the Ka band without the need for prohibitively large external fields.

This topic seeks the identification of a ferroic material and device geometry for a frequency-agile Ka band filter and a subsequent device demonstration with tuning fields generated by monolithically integrated circuitry. Features of the filter that should be targeted are: (i) low insertion loss, targeting < 1 dB, (ii) high out-of-band rejection, targeting > 20 dB, (iii) small size with preferably integrated solutions, (iv) the ability to operate at high power levels, targeting > 2 Watts, (v) low power consumption in the device and control circuit, (vi) fast switching speed, and (vii) temperature stability. Theoretical analysis of ferroic materials and candidate device designs are sought to determine device characteristics. The control circuit is also an important part of the system and offerers are encouraged to consider this aspect of the system. Microelectromechanical systems (MEMS) technologies have not been able to collectively address all of the above requirements and novel alternate technological solutions are encouraged. The resulting data will be used to produce a device design, process flow and test plan for a working prototype device to be fabricated and fully tested in Phase II.

PHASE I: The offerer will demonstrate feasibility and predict device performance through extensive theoretical investigation and modeling. The offerer will develop and document the design, decision path forward and performance testing plan that will lead to a working prototype in Phase II.

PHASE II: The offerer will construct, test and evaluate the performance of the fully packaged device designed in Phase I, including documentation of the final design and performance. The offerer will further provide a cost model and draft a preliminary path to large-scale commercial manufacturability of the device.

PHASE III: This device and variants thereof can serve as an integral component of numerous commercial applications including light-weight satellite communications, Local Multipoint Distribution Services (LMDS) systems, network analyzers and spectroscopic instrumentation.

REFERENCES:

1. M. K. Roy and J. Richter, "Tunable ferroelectric filters for software defined tactical radios", presented at the 15th IEEE International Symposium on the Application of Ferroelectrics, July, 2006.
2. E. Schloemann, et. al. J. Appl. Phys. 63, 3140 (1988). (Fe, ferromagnetic, no dielectric)
3. B. Kuanr, et. al. IEEE Trans. on Mag. 41, 3538 (2005). (ferromagnetic w/ dielectric; avoids loss tangent issues.)

KEYWORDS: Microwave, millimeter wave, Ka band, filter, ferroics, ferroelectric, ferromagnetic

A07-T010 TITLE: Development of Amorphous Alloy Surface Coatings as Replacement for Chromate Technology

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The goal of the research is to identify cost effective manufacturing processes which are capable of production of environmentally benign amorphous alloy surface coatings as replacement for chromate technology. These surface coatings shall exhibit extremely high strength and modulus and provide the potential for very effective friction, corrosion, and sand erosion resistance.

DESCRIPTION: Historically, chromium plating is used in a wide variety of applications from decorative hardware to tribological friction/wear coatings for aerospace. Electrodeposited chromium films are highly effective in both their corrosion resistance and mechanical properties. However, hard chrome is plated in the hexavalent state and in this form any residuals from processing are highly toxic. The recent reduction in maximum allowed exposure level of chromate ions (reduced from 52 to 5 ìg/cubic meter and the eventual target is 50% below that level) presents a huge technical challenge to meet this environmental standard. One way to meet the new standard is to find materials solutions that use alternative technologies to electrodeposited chromium. It has been shown that bulk metallic glass alloys have extremely high strength and modulus, and also have the potential for very effective corrosion resistance given the lack of defects usually associated with polycrystalline materials. However, relatively little attention has been paid to metallic glass coatings that could fully address the issue at hand.

To be successful the following challenges must be met. (1) Develop coatings that can replace hard chrome for a variety of applications. It would be essential that these coatings be processed in a mode that would be environmentally benign and match, or preferably improve on, the properties established for electrodeposited chromium. (2) The coatings must have sufficient stability to maintain performance at high temperatures, for example, the nature and integrity of the coating interface with the substrate will require mechanical testing to demonstrate sufficient stability. (3) Coating properties such as thin film structure, stability and chemistry need to be verified using the best available means of determining the nature of thin amorphous films, for example, using advanced synchrotron scattering methods, transmission electron microscopy or any other certification analysis that might be applicable. (4) The development of these chromate replacement coatings must be accompanied with a realistic plan for implementation based on collaboration with an industrial partnership capable of eventual production of technical parts.

In summary, the program must include a research plan that will lead to the discovery of advanced amorphous alloy coatings capable of replacing hard chromium coatings; a materials characterization scheme that can verify the nature of the amorphous structure as a function of processing and testing; a systematic evaluation of the materials in conjunction with their mechanical and chemical properties, and finally a feasible plan for manufacturing useful products.

PHASE I: Investigate and demonstrate innovative alloy materials and cost effective growth methods to achieve environmentally benign hard coatings; yet match, or preferably improve on, the properties established for electrodeposited chromium. Analyze the feasibility of producing the phase structure, alloy stability, and chemistry needed to produce thin amorphous films. Analytically verify using the best available means, such as, advanced synchrotron scattering methods and transmission electron microscopy the phase stability necessary to provide the required corrosion resistance and mechanical properties. Develop prototype films which demonstrate extremely high strength and modulus with the potential for very effective corrosion, friction, and sand erosion resistance.

PHASE II: The small business should implement the cost effective manufacturing processes identified in phase I. This should include both growth and characterization of the environmentally benign amorphous alloy surface coatings. Implement the development of films with extremely high strength and modulus that demonstrate improved properties such as corrosion, friction, and sand erosion resistance. Demonstrate repeatable on demand manufacture of the amorphous alloy coatings. Explore major cost and reliability issues associated with manufacturing of commercially viable hard coatings, that is, development of reliable, cost-effective manufacturing processes that can be implemented as a relatively simple well-known manufacturing process.

PHASE III: This manufacturing process will offer the opportunity to better control and optimize material properties to enable next generation hard coatings. The effort is intended to lead to the development of a portfolio of hard coatings with properties tailored for specific Army applications as well as for homeland security, homeland defense, and commercial applications. These films are also expected to enable critical advances in coating performance and reliability, for example, coatings with extremely high strength and modulus, corrosion and sand erosion resistance. Commercially, replacement of electrodeposited chromium coatings is of paramount importance in order to meet the technically challenging environmental standards of the present and the future. Thus, the commercialization stage will include demonstration of the many advantages afforded by successful development of amorphous alloy surface coatings with extremely high strength and modulus, corrosion and sand erosion resistance followed by launch of improved and new coatings into the commercial sector.

REFERENCES:
1. T. Hurkmans, J. Kubinski, et al., "Perspective for Replacement of hard Chrome by PVD," Proc. 42nd Annual Tech. Conf. of Soc. Vacuum Coaters, 364 (1999).
2. Duclos, "Technologies for Chromium Replacement," Advanced Mater. & Processes 159(2), 49 (2001).
3. Navin, P. Panjan and I. Milosev, "PVD coatings as An Environmentally Clean Alternative to Electroplating and Electroless Processes," Surface & Coatings Technology 116-119, 476 (1999).

KEYWORDS: Amorphous alloy surface coatings, on demand manufacturing, on demand production, effective friction resistance, effective corrosion resistance, effective sand erosion resistance, and on demand production of amorphous alloy surface coatings.

A07-T011 TITLE: A Compact Membrane-Reactor Methanol Reformer

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Design, construct, and demonstrate the feasibility of a compact methanol fuel processor utilizing a micro membrane-reactor that supplies hydrogen for 72 h to a 20 W hydrogen-air, proton exchange membrane fuel cell. The fuel processor system should have a minimum fueled energy density of 1.5 kWh/kg and not require maintenance for 500 h in use.

DESCRIPTION: The low-temperature proton exchange membrane fuel cell (PEM FC) is a candidate energy converter for a compact person-portable 20 W power system for the soldier system. The most effective PEM FC from an energy efficiency and power density perspective is the hydrogen-air system, although the supply of hydrogen remains problematical. There is need for a safe and compact hydrogen generator that is fueled by an energy-dense fuel. Partial oxidation of methanol is a possible means to produce hydrogen at the 20-W level, if the unit operations of the fuel processor are accomplished within a microchemical systems approach (1-3). Recently, MIT researchers have demonstrated (4) that a metal-oxide partial-oxidation catalyst coated onto a thin-film hydrogen-selective Ag-Pd membrane may be used to produce hydrogen of purity to support a PEM FC. This so-called membrane-reactor combines a reactor and product-gas separator into one process that, in addition to reducing the unit-operation count, advantageously heat integrates the reactor and separator processes. The micro membrane-reactor may have the potential to enable a compact microchemical fuel processor system to supply hydrogen for the soldier's PEM FC needs. There remains, however, issues that must be addressed before a micro membrane-reactor based fuel processor could be proven viable in this application, which is the focus of this topic.

Phase I: Demonstrate experimentally that a fuel processor utilizing a micro membrane-reactor may be used to produce hydrogen from methanol using air as the oxidant. The hydrogen stream must be at atmospheric pressure or greater and not require the use of a sweep gas. Based upon the experimental results, report and discuss the size and weight of a methanol fuel processor system (including all balance-of-plant components and packaging) to produce hydrogen at a rate and purity to support a 20 W PEM FC for 72 h..

Phase II: Design, construct, and evaluate a micro membrane-reactor based methanol-to-hydrogen fuel processor intended to supply hydrogen at sufficient rate and purity to support a 20 W PEM FC system for 72 h. The complete compact fuel processor system (membrane-reactor, heat exchangers, pumps, packaging, etc ..) must have a minimum fueled energy density of 1.5 kWh/kg. Demonstrate maintenance-free run times of 500 h or greater. Deliver one complete system to the Army.

Phase III: Developments in improved hydrogen sources for fuel cells will have impact on a wide range of military uses as well as commercial power sources such as emergency medical power supplies, recreational power, etc…

REFERENCES:
1. K. Jensen, AIChE J (1999) 45(10), 2051-2054
2. L.R. Arana et al., J. Microelectromechanical Systems (2003) 12(5), 600-612.
3. J. Holladay et al., Chemistry Reviews (2004) 104, 4767-4790.
4. B.A. Wilhite et al., Advanced Materials (2006) 18, 1701-1704.

KEYWORDS: methanol, fuel-reformer, fuel cell, compact power, membrane reactor

A07-T012 TITLE: <u>Molecular Shape Detection for Chemical Analysis</u>

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: A detector that employs Rydberg "fingerprint" spectra to provide molecular shape analysis that, joined with mass spectrometry, will identify molecular isomers and conformers. This detector will enable a major increase in selectivity for threat identification.

DESCRIPTION: Mass spectrometers (MS) are powerful and widely used tools for molecular analysis in chemical and pharmaceutical industries, for environmental analysis, in forensic labs, and in basic research. Army scientists use MS in the lab and soldiers use MS in the field: for example, MS is on-board the German FOX Chem/Bio detection vehicle. MS can measure molecular mass with high accuracy and, with this information, the atomic composition can be determined. But the atomic arrangement or molecular shape cannot be determined. (Note that, even for only three different atoms, there are four principal, different molecular arrangements and the standard MS cannot distinguish among them.) Research at Brown University showed, in 2005, that excited electronic (Rydberg) states could distinguish among molecular shapes (isomers) for several different atomic compositions. Those workers suggested that laser-induced Rydberg spectra could provide "fingerprints" that, joined with MS molecular mass spectra, would enable unambiguous identification of molecular structures (isomers) and, further, different molecular shapes (conformers) of the same isomer.

PHASE I: (Feasibility Study) Demonstrate in-house measurement of Rydberg fingerprints (Molecular Shape Detection) for three sets of molecular isomers. Demonstrate integration of Rydberg and mass spectra to identify different molecular isomers. Develop designs for laser source/Rydberg detectors that can be integrated into mass spectrometers to enable isomers and conformers identification. Design criteria must include: simplicity and minimum number of parts, ruggedness, and range of compatibility with existing mass spectrometers. Provide cost estimate for detector.

PHASE II: (Prototype Delivery) Year 1: build breadboard Rydberg/mass spectrometer system(s) using designs from Phase I and demonstrate joint detector operation for isomer identification. Provide data on maximum mass range for which system is valid (this will depend on mass spectrometer design chosen for tests) Year 2: build prototype suitable for adoption by commercial mass spectrometer instrument manufacturer. Develop Rydberg detector designs compatible with other mass spectrometer designs.

PHASE III: Mass spectrometry is one of the most widely used molecular analysis methods, consequently any improvement or advance will be widely adopted. One major commercial use of a molecular shape detector will be in the pharmaceutical industry: different molecular isomers often show greatly different biological activity. Because different molecular isomers often show strongly different toxicity, this detector will be useful for environmental analysis. In both cases, use of this detector will greatly speed analysis: the alternative would be submission of the sample to NMR (nuclear magnetic resonance) analysis – slow, expensive, and difficult to use with a small sample. The Molecular Shape Detector will increase the selectivity of MS for Army use in threat detection: chemical and biological agents, explosives, and industrial chemicals.

REFERENCES:
1. Gosselin and Weber, "Rydberg Fingerprint Spectroscopy: A New Spectroscopic Tool with Local and Global Structural Sensitivity", J. Phys. Chem. A 2005, 109, 4899-4904

KEYWORDS: mass spectrometry, molecular shape analysis, environmental analysis, Rydberg states, explosives detection, chem/bio detection

A07-T013 TITLE: Dynamic Data-Driven Prognostics and Condition Monitoring of On-board Electronics

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Development of dynamic data-driven prognostic tools to generate advanced warnings of anomalies and failures in electronics

DESCRIPTION: Maturity of engineering and scientific theories of control, communication and computing in the recent decades has facilitated creation of modern weapons and platforms that are highly complex systems. While the complexity remains largely hidden during the normal phase of operations, it becomes acutely conspicuous when contributing to rare cascading failures. From this perspective, a major goal for enhancement of reliability and availability of weapon systems is reduction of the probability of catastrophic failures without any significant compromise of their service quality and performance.

The objective of the project is to develop and demonstrate a library of predictive algorithms based on advanced signal analysis and pattern recognition techniques, such as Rao-Blackwellised Particle Filtering (RBPF), Symbolic Time Series Analysis (STSA), and Artificial Neural Networks (ANN), which identify the signatures of a malfunctioning system by comparison with those of the normally functioning system, thereby allowing prognosis of specific malfunctioning machines or systems well ahead of their occurrence. A prognostic system, which is able to provide an accurate picture of forthcoming faults and component degradation and to serve as predictive indicators of failures, will be extremely useful for the crew. The noble advantages include taking timely actions to avoid costly or catastrophic damage to critical Line Replaceable Units (LRUs) and to maintain availability/readiness rates for weapon systems.

The development of the predictive algorithm library needs to be general in the sense that these algorithms should be able to be ported to different computational platforms and environments. However, to test and prove the efficacy of various algorithms, the library should be developed for a specific application of the Future Combat Systems (FCS). The FCS program is interested in developing technologies that will enable real-time prognosis & condition monitoring and remaining life prediction for its critical components.

The on-board electronics may consist of many heterogeneous subsystems and components that are interconnected together in a complex manner through active and passive feedback control. A fault in one or more component(s) may influence the outputs of several other normally functioning subsystems to cause false alarms of failure. The rationale is that a healthy subsystem would yield anomalous sensor outputs if it receives faulty inputs from its predecessor. Therefore, detection and isolation of anomalies and failure precursors in correct subsystems and components is essential for mitigation of false alarms. On the other hand, prevention of catastrophic failures, due to (possibly) cascaded faults, also requires fault location, isolation and reconfiguration for enhancement of system performance and availability.

The connectivity information of LRUs and the information about possible cascades is a priori available on-board. A combination of model-based, sensor-based, and/or auxiliary information might be necessary to locate and isolate the faulty subsystem(s) for system reconfiguration. Therefore, it is imperative not only to detect the incipient faults as and when they occur, but also to isolate them as closely as possible to exercise appropriate decision and control for mitigation of its ongoing pervasion. The goal is to observe the evolution of actual system characteristics, extracted from sensor data, with reference to the nominal or the expected behavior generated by using a system model under the statistically similar conditions of disturbance and input excitation.

PHASE I: This initial phase will involve defining target events for failure prognosis. A specific component or subsystem of the FCS program will be identified, and initial tests on fault prediction should be performed for that component or subsystem using one or more analytical tools. An outline of the predictive algorithm library should be developed along with the preliminary version of the software written in a portable languages.

PHASE II: The next phase will involve develop+ing the predictive algorithms in the library, implementing them in software, and testing them against actual system failures or system events. The FCS program may allow the contractor to model one or more components or subsystems as part of Phase II. The goal of this phase should be a demonstration of the predictive failure library in the field environment. The prognostic algorithms need to be evaluated on their capability to recognize various event patterns, and should be measured on accuracy (false positive/false negative) and on the prediction time (i.e., how far in advance does an algorithm correctly classify a set of data into a “bad” pattern indicating a failure state?). This phase should include the development of an architecture, in addition to the library of algorithms, that provides an automated solution for data collection, data integration, transformation, prediction, and display of prognostic results at a fleet level (i.e., for failure prediction on multiple systems).

PHASE III: The last phase will involve commercialization of the predictive tools into a prognostic system that can be deployed across various platforms of the FCS Program.

PRIVATE SECTOR COMMERCIAL POTENTIAL: The ability to predict machine/equipment events has significant commercial potential in aircraft and other transportation, energy and process industry, manufacturing, and other industrial applications, where an advanced prognostic capability would enhance reliability, availability, and maintainability to reduce the overall life cycle cost.

REFERENCES:

1. 2001 IEEE Aerospace Conference Proceedings. Track 11: Diagnostics, Prognostics, and Health Management. IEEE Catalog Number 01TH8542C, ISBN 0-7803-6600-X.
2. Prognostics, The Real Issues Involved with Predicting Life Remaining, S. Engel, B. Gilmartin, K. Bongort, and A. Hess, Northrup Grumman, 2000 IEEE Aerospace Conference Proceedings, ISBN 0-7803-5846-5.
3. A. Doucet, N. de Freitas and N. Gordon, eds., Sequential Monte Carlo Methods in Practice, Springer, 2001
4. A. Ray, “Symbolic Dynamic Analysis of Complex Systems for Anomaly Detection,” Signal Processing, 84 (2004) 1115-1130.
5. M. Markou and S. Singh, “Novelty detection: a review—Parts 1 and 2,” Signal Processing 83 (2003) 2481–2521.
6. I. Chattopadhyay and A. Ray, “A language measure for partially observed discrete event systems”, International J. Control, Vol. 79, 1074-1086, 2006.
7. I. Chattopadhyay and A. Ray, “Renormalized measure of regular language”, International J. Control, Vol. 79, 1107-1117, 2006.
8. A. Khatkhate, A. Ray, E. Keller, S. Gupta, S. C. Chin, “Symbolic time-series analysis for anomaly detection in mechanical systems”, IEEE/ASME Transactions on Mechatronics, Vol. 11, 1-9, 2006.
9. S. Gupta, A. Ray, and E. Keller, “Identification of statistical patterns in complex systems via symbolic time series analysis”, ISA Transactions, Vol. 45, 1-14, 2006.

KEYWORDS: fault detection and isolation, catastrophic failures,
Rao-Blackwell particle filtering, symbolic time series analysis, future combat systems, predictive algorithm library

A07-T014 TITLE: Discontinuous Element Software for Computing 2D and 3D Failure of Materials under Ballistic Impact

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Design and develop modular finite element software based on discontinuous and/or continuous elements in a meshed or meshless Lagrangian framework to compute 2D and 3D failure of materials under ballistic impact.

DESCRIPTION: Adiabatic shear and spall fracture in solid materials have been extensively studied over the past four decades, with much of the current status of the fields being summarized in [1,2]. Recent theoretical successes [3,4,5] have been achieved in overcoming some of the challenges identified by prior research. A major challenge for numerical modeling of shear bands concerns the establishment of intrinsic length scales that presumably may alleviate mesh size dependency. Classical rate-independent plasticity theory lacks an intrinsic length scale, and consequently mesh-dependency issues have been addressed by various, often ad hoc, regularization strategies, including adoption of rate-dependent, non-local, and/or strain gradient constitutive models. Mesh-alignment sensitivity is commonly encountered because the finite element mesh size is often of size equal to or larger than the intrinsic length scale of the constitutive model. Numerical modeling of spall failure includes discretization-dependency issues for free surface creation accompanying void initiation and growth. Brittle fracture, however, has had significant recent success, at least for limited numbers of cracks. Meshless strategies have demonstrated some success in overcoming the mesh-alignment problem [3]. The width of a shear band is discussed in [1]. Recent research has indicated that another important length scale for shear bands, the most probable allowable spacing of bands, may be described by a new and previously unknown scaling law [6]. This recent success in theoretical shear-band and spall modeling has not been accompanied by complete incorporation of corresponding numerical techniques in software packages used for design of armor with improved performance under ballistic impact. The generation of modular software enabling easy user insertion of constitutive models for material deformation and criteria for initiation, evolution, and coalescence of damage entities is a priority.

PHASE I: Carry out a design study for modular finite element software based on discontinuous and/or continuous elements in a meshed or meshless Lagrangian framework to compute failure of materials under ballistic impact in two and three spatial dimensions (2D and 3D). Criteria triggering introduction of discontinuities must be part of the computational process, not purely the result of a priori input from the user. For example, a shear band insertion criterion should depend on internal state variables, preferably in a thermodynamically consistent way for plastic materials, accounting for energy transfer from/to the failure front to/from the surrounding material, as opposed to the widely used cohesive zone method of elastic energy release due to bond breaking. After introduction of the discontinuity, the temperature and jump in velocity across the element have to be controlled in such a way as to mimic the true, continuous, but very rapidly varying fields across the discontinuity for both shear bands and spall fracture. For example, the particle velocity and the temperature profiles typically associated with a shear band change in one direction far more rapidly than can be accommodated by convenient grid or element size. The transition across the band is in effect an internal boundary layer that is forced by a material instability (strain softening driven by heat from plastic working). The physics to be represented is complex and has not previously been incorporated into robust, user-friendly software. Similarly, spall failure should be exercised numerically in a physically realistic, history-dependent way, as recent research [5] indicates that spall strength may be influenced by local inertia around growing voids in the vicinity of the spall plane.

The discontinuities in the field variables should minimally include tangential jumps in displacement as well as cracks or voids that may open, close, and slide. The discontinuous and continuous elements should be integrated into a complete computational procedure that accurately captures the dynamics of high-strain-rate failure processes exhibiting discontinuities in the field variables appropriate for adiabatic shear bands, spall planes and cracks.

Flexible user selection and control over criteria for initiation and propagation of damage entities should be based upon initial conditions and solution trajectories (for example, the local stress and temperature state). The computational procedure must be able to handle complex geometries and heterogeneous material properties corresponding to realistic crystalline microstructures. Materials of primary interest are polycrystalline metals and ceramics, and the computational procedure should be applicable at resolutions from microns to millimeters. At the end of Phase I, the contractor should present 1) a complete design for the modular 2D and 3D finite element software, 2) theoretical justification for the class(es) of 2D and 3D discontinuous elements proposed for that software, 3) conditions for on-the-fly insertion of these discontinuous elements into the computational process and theoretical justification of those conditions, 4) statements about expected limitations of the software (for example, poor performance under certain material or computational conditions or inability to handle various strain rates), 5) preliminary evidence that the 2D and 3D software will accurately represent the dynamics of a large class of conditions. Preliminary evidence may be theoretical evidence, 2D (or 3D) computational evidence and/or any other evidence that would be acceptable to theoreticians and practitioners.

PHASE II: Develop the modular 2D and 3D finite element software designed in Phase I. This software should be compatible with or, preferably, directly plug into one or more widely used finite element software systems for computing response to ballistic impact (for example, ABAQUS, EPIC, DYNA). Carry out validation and verification of this software. Confirm that the accuracy and limitations of the software are consistent with the estimates of Phase I or correct those estimates. Carry out a demonstration of the software. At the end of Phase II, present the software, a user manual for the software and a summary of the verification/validation, accuracy and limitations of the software.

PHASE III: The system produced by this effort will support a broad range of military and civilian applications where computation of material response under large strains and strain rates is required. Military applications include design of advanced anti-ballistic and anti-blast (improvised explosive device„ŸIED) armor and testing via simulation. Possible civilian applications include design of materials and structures for mitigation of effects from crash and explosions and optimization of high speed cutting and forming operations.

NOTE: Both meshed and meshless finite element methods are acceptable. If a meshless method is proposed, the computational load must be shown to be not much larger than that for a meshed method.

REFERENCES:
1. Wright, T.W., 2002, The Physics and Mathematics of Adiabatic Shear Bands, Cambridge University Press.
2. Antoun, T., Seaman, L., Kanel, G.I., Razorinov, S.V. and Utkin, A.V., 2003, Spall Fracture, Springer.
3. Li, S., Hao, W and Liu, W.K., 2000, Int. J. Solids Structures 37, 7185-7206.
4. Schoeneld, S.E. and Wright, T.W., 2002, Int. J. Solids Structures 40, 3021-3037.
5. Molinari, A. and Wright, T.W., 2005, J. Mech. Phys. Solids 53, 1476-1504.
6. Zhou, F., Wright, T.W. and Ramesh, K.T., 2006, J. Mech. Phys. Solids 54, 1376-1400.

KEYWORDS: ballistic impact, discontinuous element, finite element, shear band, spall plane

A07-T015 TITLE: Portable Fully-Automated Soil Property Measurement Probe

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop an innovative instrumented portable device that can make rapid in-situ measurements of the shear, sinkage and frictional properties of soil.

DESCRIPTION: Floatation, mobility, and tractive ability of off-road vehicles are of key concern for engineers involved in the design and testing of agricultural, construction, forestry, military, and mining equipment. Reduction in vehicle weight along with an increase in soil-traction device contact area has successfully overcome issues related to floatation. Mobility and tractive ability of off-road vehicles continues to be challenging problems because of the complexity of soil-traction device interaction process. Although soil is the key component of this soil-traction interaction device interaction process, it is often very poorly accounted for in mobility models. Several researchers have tried to identify soil properties or parameters to adequately represent soil in a traction prediction model

(Janoshi and Hanamoto, 1961; Bekker, 1969; Yong et al., 1984; Wong, 1989; Freitag, 1966; Turnage, 1972; Wismer and Luth, 1973). Freitag (1966), Turnage (1972), Wismer and Luth (1973) have used dimensionless terms based on soil cone index values known as "numerics" such as clay numeric, sand numeric, or wheel numeric to represent soil. The cone index is a composite soil parameter obtained by pressing a standard cone penetrometer (ASAE Standards, 2000a and b) into the ground at a penetration rate of 72 in/min. It is expressed as the force per unit area required to push the penetrometer through a specified small increment of soil. One of the main advantages of the cone penetrometer is its simplicity and ease with which it can be used to obtain field data. It appears to be quite useful in predicting motion resistance of vehicles. Motion resistance of off-road vehicles is related to the compressibility of soil and that of the traction device. Therefore, cone index appears to be an adequate indicator of compressive ability of soil. Tractive characteristics of off-road vehicles depend on shear and sinkage characteristics of soil (Bekker, 1969; Yong et al., 1984; Wong, 1989; Upadhyaya and Wulfsohn, 1989). Upadhyaya et al. (1993) found that soil cone index values were not sufficient to determine tractive ability of vehicles. Wills (1964) developed a hydraulic bevameter that could measure plate sinkage and torsional characteristics of soil. Upadhyaya et al. (1993) developed an instrumented soil test device that could measure soil sinkage, shear, and cone index values. Upadhyaya and Wulfsohn (1993) and Upadhyaya et al. (1989) reported better success in predicting tractive ability of radial tires using soil sinkage and shear parameters compared to soil cone index values. Bevameter or other currently available instrumented devices that provide shear and sinkage characteristics of soil are research devices and are not as simple and easy to use as a standard cone penetrometer.

PHASE I: Develop a design a proof-of-concept laboratory prototype for innovative instrumented portable device with the capability for in-situ measurements of the shear, sinkage and frictional properties of soil. This device would operate like a cone penetrometer to automatically obtain three cone index values with depth as pushed into the soil - the (i) commonly used Cone Index (CI), (ii) the Friction Index (FI) which is the ratio of the frictional torque on the soil test unit to the CI, and the (iii) Shear Index (SI) which is the ratio of the shear torque on the soil test unit to the CI.

PHASE II: The Phase II program will be an engineering development effort to bring the Phase I instrumented soil test device prototype to a functional state for field deployment and to add enhanced capabilities, readily COTS available or demonstrated under laboratory conditions, that will produce a rapdly-deployable and versatile sensor to characterize surface soil for use in both direct in-field applications and in operational mobility prediction models. These capabilities include (i) a dielectric or near-infrared spectroscopy based moisture sensor, (ii) a compact data logging system, and (iii) a displacement senor (rotary potentiometer) so that torque versus displacement characteristics can be measured and soil shear modulus determined, and (iv) an electrical or hydraulic drive to automate the rotation of the soil test device. The Phase II effort will develop versions of the technology that can be deployed as a man-portable probe and as a probe that can be mounter and deployed on a small remote-operated robotic vehicle.

PHASE III: Development of a commercializable/marketable instrumented portable probe that can make in-situ measurements of the shear, sinkage and frictional properties of soil. Potential Military applications are defined in the Future Force operational requirements for Unmanned Ground Vehicle reconnaissance that include the real-time measurement of soil properties for operational mobility and military engineering operations. Multiple civilian applications are envisioned in areas such as road construction, agriculture, mining, and forestry.

REFERENCES:
1. ASAE Standards, 2000a, ASAE Standards S313.3. Soil cone penetrometer: ASAE, St. Joseph, MI.
2. ASAE Standards, 2000b, ASAE Standards EP542. Soil cone penetrometer: procedures for using and reporting data obtained. ASAE, St. Joseph, MI.
3. Bekker, 1969, Introduction to Terrain - Vehicle Systems. University Michigan Press, Ann Arbor.
4. Freitag, 1966., A dimensional analysis of the performance of pneumatic tires on clay. J. Terramechanics. 1:7-30.
5. Garciano, Upadhyaya, Jones, and Jersey, 2006. Determination of the soil failure zone around a cone penetrometer under laboratory conditions. J. Terramechanics.
6. Janosi and Hanamoto, 1961, Analysis of the pull versus slip relationship for track laying vehicles. Report No. 69. Land Locomotion Laboratory, Michigan.
7. Turnage, 1972, Tire selection and performance prediction of off-road wheeled-vehicle operations. 4th Int. conference, ISTVS, Stockholm, Sweden.

8. Upadhyaya, Wulfsohn, and Mehlschau, 1993, An instrument device to obtain traction related parameters. J. Terramechanics 30(1):1-20.
9. Upadhyaya and Wulfsohn. 1993, Traction prediction using soil parameters obtained with an instrumented analog device. J. Terramechanics. 30:85-100.
10. Wismer and Luth. 1973, Off-road traction prediction for wheeled vehicles. J. Terramechanics. 10:49-61.
11. Wong, 1989, Terramechanics and Off-road Vehicles. Elsevier. Amsterdam.
12. Yong, Fattah, and Skiadas. Vehicle traction mechanics. Elsevier, NY 1984; 307.1.

KEYWORDS: soil penetrometer

A07-T016 TITLE: Synthesis and Scaleup of Fuel-Cell Compatible Alkaline Electrolyte Membranes

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Synthesize a hydroxyl-conducting alkaline exchange membrane (AEM) electrolyte and measure its mechanical, chemical, and electrochemical properties relevant for fuel-cell application. Develop and demonstrate feasibility of scale up procedures to produce AEM polymer materials intended for use by fuel-cell developers.

DESCRIPTION: Proton exchange membranes (PEM) are the proton-conducting electrolyte in low-temperature (~ 100 C) fuel cells (FCs). PEM FCs are being examined for DoD applications spanning power demands from mW to kW and are a candidate compact power system for the soldier. The acid environment of the PEM requires noble metal electrocatalysts, which increases lifecycle costs for this power source and limits fuel choice to hydrogen or methanol. In addition, water-management issues arise because of electroosmotic pumping of water from anode to cathode, and care must be taken in design and operation of the PEM FC to avoid dry-out conditions at the anode or flooding at the cathode. In principle, an alkaline exchange membrane (AEM) as a hydroxyl-conducting electrolyte could improve FC performance over state-of-art PEM FC technology and alleviate these problems (1, 2). The potential advantages and challenges of an AEM FC have been recently summarized (2). For example, non-noble (low-cost) electrocatalysts can be employed in both electrodes of an AEM FC, with an improved energy efficiency because of lower anode (fuel) and cathode (air) overvoltage; cathode flooding is less problematical; more complex fuels may potentially be employed since C-C bond breakage is more facile in alkaline environment; etc … Challenges facing AEM FCs include the need to ensure carbon dioxide uptake into the AEM does not result in reduced ionic conductivity; chemical, electrochemical, and thermal stability of the AEM under FC operating conditions; etc… Unlike PEMs, there is no commercial source for AEMs to support development of AEM FC technology. Advances in polymer chemistry and polymerization processes such as anionic polymerization (3), atom-transfer-radical polymerization (ATRP) (4); radiation grafting (5), among others, support an examination of means to synthesize new and novel AEM polymer materials and examine their properties for possible enabling use in AEM FC power systems. Because AEM materials are not readily commercially available, it is important that the manufacturing processes to synthesize the AEM be scaleable to provide sufficient samples to fuel-cell developers for evaluation.

PHASE I: Synthesize a hydroxyl-conducting AEM polymer with controllable ion-exchange capacity. Characterize the polymer to include: chemical and electrochemical stability; equilibrium uptake of CO_2 from air; liquid-water wetted ionic conductivity; and tensile strength, all over the temperature span of 20 to 80 C. Present a process to scale up production of the AEM.

PHASE II: Upon optimization of the synthesis chemistry with a focus on improving AEM FC relevant properties, design, construct, and demonstrate feasibility of the process to produce commercial quanitities of the optimized AEM polymer.

PHASE III: Developments in improved fuel cells will have impact on a wide range of military uses as well as commercial power sources such as emergency medical power supplies, recreational power, etc…

REFERENCES:
1. G.G McLean et al., International J. Hydrogen Energy, 27 (2002) 507-526.
2. J.R. Varcoe and R.C.T. Slade, Fuel Cells, 5 (2005) 187-200.

3. H. Hsieh and R. Quirk, Anionic Polymerization: Principles and Practical Applications, Marcel Dekker (1996).
4. T.E. Patten and K. Matyjaszewski, Advanced Materials, 10 (1999) 901-915.
5. T.R. Dargaville et al., Progress in Polymer Science, (2003) 28(9) 1355-1376.

KEYWORDS: alkaline exchange membrane, fuel cell, polymer

A07-T017 TITLE: Ultrasound Assisted Oxidative Desulfurization of JP-8 Fuel

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a process based upon the ultrasound assisted oxidative desulfurization (UAOD) method to remove sulfur-containing compounds from JP-8 fuel. The system will supply desulfurized JP-8 fuel at 10 g/min with sulfur content no greater than 10 ppm, which is a sufficient rate and purity to support a 2 kW solid oxide fuel cell after fuel reformation.

DESCRIPTION: Solid oxide fuel cell (SOFC) power systems are a potential solution to a variety of Army power needs ranging from tens of W to tens of kW. Because SOFCs operate at high temperature, they can be fueled with H2 streams containing significant CO content, which may be supplied by reformation of the Army logistics fuel JP-8. Catalysts in the reformation reactors are, however, poisoned by sulfur within the fuel, which necessitates a sulfur-removal step prior to feeding JP-8 to the fuel processor. The common high-temperature and -pressure hydrodesulfurization technology practiced at the refinery scale is not feasible for the power levels described above and alternative approaches to eliminate sulfur must be employed. Recently, an innovative ultrasonic method to remove sulfur from hydrocarbons has been demonstrated (1-3). The ultrasound assisted oxidative desulfurization (UAOD) process selectively oxidizes sulfur in common sulfur-containing molecules in diesel (e.g., thiophenes, benzothiophenes, and dibenzothiophenes) to a sultone that, because of its polarity, may be removed via selective adsorption. The sonoreactor assists in effecting a high-rate of catalytic reaction using hydrogen peroxide as the oxidant while the sono-energy emulsifies the aqueous peroxide-containing stream with the fuel. The UAOD process is carried out at ambient temperature and atmospheric pressure and employs common unit operations. Because of its simplicity and ambient operating conditions, the UAOD process has the potential to form the basis of a desulfurization system in the power range described above; however, there remain questions and issues that must be addressed to gauge its potential to fill this need for the military. For example, the UAOD process has been demonstrated on diesel but can it be effective if fed the higher-sulfur content JP-8? The UAOD process employs polyoxometalate homogeneous catalyst, surfactant, and phase-transfer agent that must be separated from the desulfurized fuel and recycled. Can these processes be performed in simple and compact hardware? Can a heterogeneous catalytic fixed-bed process be employed and thereby eliminate the need for (homogeneous) catalyst removal and recycle? The sultone adsorbent must be either regenerated or replaced: which, if either, is to be preferred? Hydrogen peroxide is used in the process. Can this oxidant be generated in-situ by, for example, ultrasound-induced decomposition of water, as demonstrated by Hua and Hoffman (4)? These and other issues must be considered if a practical and sustainable UAOD-based desulfurization process is to be fielded.

PHASE I: Demonstrate that the UOAD process can be used to desulfurize JP-8 to 10 ppm S. Develop and evaluate at the bench scale approaches to enable a practical UOAD desulfurization process such as heterogeneous catalysts, minimization of oxidant reagent needed, innovative phase-separation and recycling methods, etc … Present and discuss a design of a complete UOAD-based system to desulfurize 10 g/min of JP-8 fuel to no greater than 10 ppm sulfur, with a focus on size and weight of each unit operation in the system.

PHASE II: Design, construct, and evaluate a complete UOAD-based system to desulfurize 10 g/min of JP-8 fuel to no greater than 10 ppm sulfur. At the minimum, the system should not require maintenance for 500 h of runtime. The (dry) system must be self-contained and person-portable. Deliver one complete JP-8 desulfurization system to the Army.

PHASE III: Developments in fuel processing systems for fuel cells will have impact on a wide range of military uses as well as commercial power sources such as emergency medical power supplies, recreational power, etc…

References:
1. H. Mei, B.W. Mei, and T.F. Yen, 2003, Fuel, 82(4), 405-414.
2. C Li et al., Chemistry – A European J., 2004, 10(9), 2277-2280.
3. C. Li et al., Topics in Catalysis, 2005, 35(1-2), 169-175.
4. I. Hua and M.K. Hoffman, 1997, Environ. Sci. Tech., 31, 2237-2243.

KEYWORDS: N/A

A07-T018 TITLE: High efficiency deep green light emitting diode

TECHNOLOGY AREAS: Electronics

OBJECTIVE: The goal of this research and development is to create a light emitting diode (LED) with enhanced output using nanoparticles.

DESCRIPTION: Efficient solid state white lighting currently suffers from the lack of an efficient deep green (555-585 nm) emitter. Green LEDs have not been able to match the performance of aluminium indium gallium phosphide (AlInGaP) and gallium nitride (GaN) emitters which emit in the yellow-red and blue wavelengths respectively. Because 555-585 nm is the region of the visible spectrum to which the human eye is most sensitive, it is the most critical component of white light technology. Quantum well (QW)-based LEDs can be readily engineered to emit in this wavelength range but are inefficient, suffering from non-radiative decay due to material quality. This inefficiency can be addressed by providing another radiative decay route for carriers which can compete with the non-radiative transitions. Quantum dots (QD) with strong luminescence, if placed in close enough proximity to the quantum well for significant tunneling to occur, can provide an additional radiative decay channel. This effectively can compete with the non-radiative channels and enhance the efficiency of green LEDs. Obtaining sufficient coupling between the quantum well and quantum dot is difficult with typically spherical nanoparticles. Research is sought to prove the effectiveness of this technique by (i) identifying a non-spherical quantum dot that can provide strong coupling to a quantum well, (ii) modeling the impact of the additional radiative decay channel, and (iii) demonstrating the technology through a working prototype. The efficiency goal for the device is > 120 lumens per Watt of input power.

PHASE I: The offerer will demonstrate feasibility and predict device performance through extensive theoretical investigation and modeling of coupled QW/QD structures, identifying at least one type of non-spherical quantum dot that can be incorporated in an QW-based LED. If the modeling determines that the technique can significantly increase efficiency above current technology, the offerer will develop and document the design, decision path forward and performance testing plan that will lead to a working prototype in Phase II. A Phase II award is contingent upon a design that provides an efficiency gain sufficient to support a commercially viable technology.

PHASE II: The offerer will construct, test and evaluate the performance of the fully packaged device designed in Phase I, including documentation of the final design and performance. The offerer will provide a cost model and draft a preliminary path to large-scale commercial manufacturability of the device. The offerer will further construct designs for higher efficiency and scaled devices for higher output power.

PHASE III: Civilian applications of this device include general lighting, display illumination and spectroscopic light sources.

REFERENCES:
1. M. Achermann, et. al., NanoLetters 6, 1396 (2006).
2. H. Tu, et. al., J. Phys. Chem. B 108, 4701 (2004).
3. Shuming Yang and David F. Kelley, J. Phys. Chem. B 109, 12701 (2005).

KEYWORDS: Light emitting diode, LED, lighting, nanoparticles

A07-T019 TITLE: Super-resolution adaptive laser beam projection system

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop concept, algorithm and hardware for high-resolution laser beam projection onto a remote, extended target though turbulent atmosphere for Army tactical applications.

DESCRIPTION: Target-in-the-loop (TIL) laser beam propagation is commonly encountered in a number of ARMY applications such as laser target designation, active imaging, directed energy systems, and tracking. It has been demonstrated recently that the conventional adaptive optics approach, based on measurement and subsequent direct conjugation of the speckle-field wave-front phase, faces serious problems in target-in-the-loop compensation scenarios with extended (resolved) targets with rough surfaces.[1] This is primarily due to the fact that this approach cannot distinguish between the contributions of atmospheric-turbulence induced phase aberrations and target-induced effects caused by the target surface roughness. This issue represents, perhaps, the most challenging case for adaptive optics applications. A prospective solution to this problem has been shown through an innovative approach where iterative real optical phase conjugation leads to formation of a stable hot spot on the target.[2] The laser system based on this new approach can be used for various Department of Defense (DOD) applications including laser communication, synthetic aperture optical imaging, laser designation, and directed energy tactical systems that can significantly increase of the power density on the target.

PHASE I: Develop a concept, algorithm, and design that will demonstrate a system architecture that is consistent with the technical goals articulated above. More specifically, the contractor should develop an initial system design that operates in the near IR and, based on this design, develop a laboratory-scale system that demonstrates the architecture feasibility for distances up to10 miles.

PHASE II: Build, test, and integrate a state-of-the-art optical system that uses this technology. This should include an optimized phase conjugation module to function with the specific optical system. This includes achieving compatibility with regard to spatial and temporal resolution for both resolved and non-resolved target, as well as optimization of control algorithms.

PHASE III: This technology has the potential to be an enabling technology for laser communications and large-aperture tactical weapon system for Army and Navy applications and space-based optical imaging systems. Military and civilian users would both benefit from the increased performance as well as reduced costs associated with dramatic reductions in the weight of such systems. Civilian applications include aberration compensation for extended-range high-data-rate laser communications, retinal imaging, optical tweezers, and high-altitude imaging for agriculture monitoring, traffic management, and law enforcement.

REFERENCES:
1. Mikhail A. Vorontsov, Valeriy Kolosov, “Target-in-the-loop beam control: basic considerations for analysis and wave-front sensing”, J. Opt. Soc. Am. A, Vol. 22, No. 1, pp.126-141, 2005.

2. “Phase conjugate laser optics”, Arnaud Brignon, Jean-Pierre Huignard, Editors, A Wiley-Interscience Publication, John Wiley & Sons, Inc., New Jersey, 2004, p. 410; V. Markov, A. Khizhnyak, D. Dirk, J. Trolinger, F. Eaton, “Optical phase conjugation for atmospheric turbulence assessment”, Proc. SPIE, Vol. 6215, pp.62150J-1 – 11, 2006.

KEYWORDS: ATR, Adaptive Optics, Turbulence, Directed Energy, Optical Phase Conjugation

A07-T020 TITLE: Fiber nonlinearity based entangled-photon sources

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Design and development of an innovative device based in optical fiber to generate entangled photons suitable for the demonstration and deployment of ultra secure quantum communication protocols in existing fiber telecommunication infrastructure.

DESCRIPTION: Quantum communication and key distribution protocols provide a capability for ultra secure communication not possible with classical communication protocols. Key to the deployment and early adoption of this technology is compatibility with existing fiber telecommunication networks. Entangled photon pairs are a critical resource for realizing these quantum communication protocols. Therefore, the efficient generation and distribution of entangled photon pairs in fiber networks is of prime importance. Spontaneous parametric down-conversion in a 2nd order (÷(2)) nonlinear crystal has been the workhorse method for generating entangled photon pairs. However, efficient coupling of the entangled photons generated by the crystal into standard optical fibers for transmission, storage, and manipulation over long distances has been an engineering challenge. Recent experiments have changed the situation by directly producing entangled photons in the fiber itself by exploiting the fiber's Kerr nonlinearity [1,2]. By cooling the fiber to liquid nitrogen temperature, a two-photon interference visibility > 98% has been demonstrated [3], which meets the requirement for entanglement based secure key distribution. Further developments have included the generation of degenerate-frequency entangled photons [4] and the use of microstructure and highly nonlinear fibers for producing entangled photons over a wide range of wavelengths (750–1560 nm) [5,6]. The latter also provides a pathway for the development of compact, integrable sources that can be fielded in the ubiquitous optical fiber infrastructure and dual use systems [7].

PHASE I: Design and demonstrate feasibility of a high-fidelity source of degenerate as well as nondegenerate polarization and time-bin entanglement that is rack mountable and deployable in a realistic field environment. The source must be able to produce photon pairs at a rate exceeding 100,000 per second out of the tips of the fiber and of fidelity sufficient to enable quantum key distribution protocols.

PHASE II: Build prototypes of the polarization as well as time-bin entanglement sources and quantify the performance metrics of two-photon interference visibility and the pair-production rate. Provide a demonstration deployment that validates the technology. The Phase-II program shall provide a plan to transition the technology to commercial development and deployment.

PHASE III: The technology developed here has impact on the successful deployment of ultra secure quantum communication networks based on existing fiber infrastructure. In addition to critical national security applications, quantum communication is anticipated to have an impact on commercial applications involving ultra secure communications, such as bank transactions. The technology developed here is also anticipated to have broader impact on photon sources for classical communications based on existing fiber networks for DOD and commercial applications.

REFERENCES:

1. M. Fiorentino, P. L. Voss, J. E. Sharping, and P. Kumar, "All-fiber photon-pair source for quantum communications," IEEE Photonics Technology Letters, Vol. 14, No. 7, July 2002, pp. 983-985.
2. X. Li, P. L. Voss, J. E. Sharping, and P. Kumar, "Optical-fiber source of polarization-entangled photons in the 1550 nm telecom band," Physical Review Letters, Vol. 94, No. 5, 053601, (2005).
3. K. F. Lee, J. Chen, C. Liang, X. Li, P. L. Voss, and P. Kumar, "Generation of high-purity telecom-band entangled photon pairs in dispersion-shifted fiber," Optics Letters, Vol. 31, No. 12, June 15, 2006, pp. 1905–1907.
4. J. Chen, K. F. Lee, J. Chen, and P. Kumar, "Fiber-based telecom-band degenerate-frequency source of entangled photon pairs," Optics Letters, Vol. 31, No. 18, September 15, 2006, pp. 2798–2800.
5. J. Fan, A. Migdall, and L. J. Wang, "Efficient generation of correlated photon pairs in a microstructure fiber," Opt. Lett. **30**, 3368-3370 (2005).
6. J. Fulconis, O. Alibart, W. Wadsworth, P. Russell, and J. Rarity, "High brightness single mode source of correlated photon pairs using a photonic crystal fiber," Opt. Express **13**, 7572-7582 (2005).
7. C. Liang, K. F. Lee, J. Chen, and P. Kumar, "Distribution of Fiber-Generated Polarization Entangled Photon-Pairs over 100 km of Standard Fiber in OC-192 WDM Environment," postdeadline paper presented at the Optical Fiber Communications Conference and the National Fiber Optic Engineers Conference (OFC/NFOEC'2006), Anaheim Convention Center, Anaheim, CA, March 5–10, 2006; paper PDP35.

KEYWORDS: Entangled photon sources, quantum communication, quantum key distribution

A07-T021 TITLE: Low Data Rate Frequency-Shifted Reference Ultra-Wideband (UWB) Communication Systems

TECHNOLOGY AREAS: Electronics

OBJECTIVE: The objective of this STTR is to develop a robust low-cost ultrawideband communication system based on the frequency-shifted reference ultrawideband (FSR-UWB) concept.

DESCRIPTION: Ultrawideband (UWB) communication systems provide the potential for extremely low power robust communication with excellent material penetration, high resistance to multipath fading and jamming, and high user capacities [1][2]. In addition, the large system bandwidth provides the potential for accurate node positioning. Hence, the realization of such a technology would significantly benefit numerous military and commercial systems, particularly those for small unit operations, sensor networks, RF tagging, industrial machinery, etc. However, the penetration of UWB systems into both military and commercial systems has been hampered by two key factors: (1) difficulty in realizing the UWB receiver, and (2) susceptibility to narrowband interference. Both of these factors have greatly limited the applicability of UWB systems, and, in particular, the latter has made UWB unattractive for military applications.

Recently, the FSR-UWB system architecture has been introduced [3]. As a variant of the standard transmitted reference (TR-UWB) concept [4], it avoids the complexity of the rake receiver and associated channel estimation by transmitting a reference signal along with the data signal. However, by offsetting this reference signal in frequency rather than time from the data signal, the unrealizable wideband delay line in the TR-UWB receiver is avoided. Since the FSR-UWB works in frequency instead of time, resulting receiver architectures will more easily mitigate narrow band interference. This effort seeks to capitalize on these recent innovations by considering the development, demonstration, and commercialization of a low-cost FSR-UWB system that is resistant to narrowband interference.

PHASE I: Research, development, and evaluation of different FSR-UWB architectures with associated narrowband interference suppression capabilities. Critical in the evaluation of each architecture is not only the performance but also maintaining the simple realization characteristics of the initial FSR-UWB system. The applicability of each architecture to various (ultrawide) bandwidths should be considered, particularly the ability to scale bandwidth in future systems. The result will be a report that clearly lays the roadmap for commercialization in at least one compelling application. If possible, a small demonstration consisting of a link or set of links should be constructed to demonstrate the system capabilities.

PHASE II: Further development of the most promising architecture from Phase I with a focus on the selected compelling application. Demonstrate a network of nodes with a fully functioning protocol stack.

PHASE III: Design, build, and test a network of fully integrated low-power nodes. Potential military applications include small unit operation communications, friend-vs.-foe identification, sensor networks, RF tagging, etc. Potential commercial applications include industrial communication and sensing, RF tagging, etc.

REFERENCES:
1. R. Scholtz, D. Pozar, and W. Namgoong, "Ultra-Wideband Radio," EURASIP Journal on Applied Signal Processing, pp. 252-272, March 2005.

2. M. Win and R. Scholtz, "Ultra-wide Bandwidth Time-Hopping Spread-Spectrum Impulse Radio for Wireless Multiple Access Communications," IEEE Transactions on Communications, Vol. 48: pp. 679-691, April 2000.

3. D. Goeckel and Q. Zhang, "Slightly Frequency-Shifted Reference Ultra-Wideband (UWB) Radio: TR-UWB without the Delay Element," Proceeding of the Military Communications Conference, October 2005.

4. R. Hoctor and H. Tomlinson, "Delay-Hopped Transmitted-Reference RF Communications," Proceedings of the IEEE Conference on Ultra-Wideband Systems and Technologies, pp. 265-270, May 2002.

KEYWORDS: Frequency-Shifted Reference Ultra-Wideband Communication

A07-T022 TITLE: Diluted-Magnetic Semiconductor (DMS) Tunneling Devices for the Terahertz Regime

TECHNOLOGY AREAS: Electronics

OBJECTIVE: The objective of this project is the design, development and demonstration of novel semiconductor quantum barrier/well devices that utilize spin-control mechanisms available in diluted-magnetic materials for achieving higher-level functionality (e.g., transistor action) at very high switching-speeds and frequencies. A successful outcome of the effort would be the experimental demonstration of enhanced or new electron-device functionality that leverages spin and charge control to significantly advance military-relevant analog and/or digital electronics within the terahertz frequency regime.

DESCRIPTION: The long-standing motivation for the use of diluted-magnetic semiconductor (DMS) structures in both electron charge/spin transport devices is for the development of ultra-capable (i.e., small, fast, etc.) computer chips that can both calculate and store data. To that end, the DMS challenge has been: (1) to optimize the magnetic properties for room temperature operation; (2) to design devices that can successfully exploit both spin and charge (electron and hole) transport capabilities; and (3) to successfully incorporate the magnetic field as a controlling element. Fortunately, important breakthroughs have occurred recently that provide new avenues for achieving these objectives. In particular, a major step with respect to optimization has occurred with the emergence of a new capability for constructing DMS semiconductors one atom at a time [1], thereby permitting, in the case of GaAs, for the optimal arrangement of manganese atoms necessary to enhance the magnetic semiconducting properties. Additionally, recent GaMnN [2] studies have demonstrated Curie temperatures in excess of 300K which allows for achieving the magnetic properties at temperatures much higher than were available before. In closely related device design advances, the lack of prior success in the development of a spin FET [3] has been dealt with through the incorporation of magnetic field effects that are transverse to the direction of transport [4]. Indeed in one key example, ferromagnetic gates were configured perpendicular to transport in the design of a spin valve in a SiO2/Si structure [5]. As an analogue to these type of ferromagnetic gates, DMS structures also offer an additional design latitude where the magnetic field can function as a control element to two-terminal devices, e.g., Resonant Tunneling Devices (RTDs) and superlattices [6, 7], and this has immediate application in the design of very high-speed switching devices and novel terahertz (THz) regime (> 300 GHz) sources [8, 9]. In realizing these magnetically-gated devices, n-type transport will be of paramount importance; and with the recent experimental demonstration of a three-terminal device based upon a GaMnAs /n+-GaAs structure with electron spin-injection by interband tunneling [10], this is now possible. Hence, it is not surprising that new types of DMS-based devices are appearing more frequently, including structures proposed as biomolecular sensors [11], a lateral superlattice [12], and spin Gunn-effect devices [13].

The aforementioned breakthrough demonstrations in DMS-based materials and heterostructure devices provide strong motivation for the development of a completely new class of very high speed/frequency functional devices. The envisioned STTR effort will seek to develop DMS-based tunneling devices by leveraging new theoretical insights and design (i.e., modeling and simulation) tools that have only recently emerged from U.S. Army supported fundamental research projects [6-9] and other similar types of endeavors. The expected outcome of the STTR project would be the experimental demonstration of increased device functionality with regard to spin and charge control, along with high-speed and/or high-frequency analog and/or digital capabilities. Furthermore, a successful effort would demonstrate the effectiveness of this new tech-nology in one or more U.S. Army and/or DoD relevant application areas – e.g., THz frequency source technology, THz frequency sensing, etc.

PHASE I: The Phase I effort should apply advanced modeling and simulation capabilities to the conceptual design of novel devices that are based upon DMS tunneling structures. Devices studies should be emphasized that seek to develop high-level functionality and enhanced capabilities for U.S. Army relevant applications at THz frequencies - e.g., high speed/frequency transistors. The Phase I studies should identify device design trade-offs and perform experimental measurement/testing for concept verification and proof-of-concept where useful.

Phase II: The Phase II effort should build and demonstrate a prototype multi-terminal DMS device capable of offering new functionality and/or superior capability for operation at THz frequencies. Relevant applications might include, but are not limited to: THz sources for use in monitoring for chemical, biological and energetic threat agents and/or THz transistors for very high-speed data and signal processing. The Phase II demonstrations should document the effectiveness of the new devices and execute optimization studies for assessing their maximum potential.

PHASE III: The initial targets for the proposed DMS technology is for highly military relevant THz applications such as power sources for threat agent detection and monitoring and very high-speed transistors for data and signal processing. This same technology would have relevance to other areas such as: novel biomolecular sensors; IR sensors; memory devices; etc, and these devices would represent a major enabler to a host of private sector electronic application areas.

REFERENCES:
1. D. Kitchen, A. Richardella, J.-M. Tang, M. E. Flatte and A. Yazdani, "Atom-by-Atom Sub-stitution of Mn in GaAs and Visualization of their Hole-Mediated Interactions," Nature, 442, 436 (2006).
2. T. Hynninen, H. Raebiger, J. von Boehm and A. Ayuela, "High Curie Temperatures in (Ga,Mn)N from Mn Clustering," Applied Physics Letters, 88, 122501 (2006).
3. S. Datta and B. Das, "Electrical Analogue of the Electrooptic Modulator," Applied Physics Letters, 56, 665 (1990).
4. S. Bandyopadhyay and M. Cahay, "Alternate Spintronic Analog of the Electro-Optic Modulator," Applied Physics Letters, 85, 1814 (2004).
5. C. Ciuti, J.P. McGuire, and L.J. Sham, "Spin-Dependent properties of a Two-Dimensional Gas with Ferromagnetic Gates. arXiv:cond-mat, 2, 0205651 (2006).
6. H.L. Grubin, "Diluted Magnetic Semiconductor Superlattices," Proc. SPIE, 6212, 621205 (2006).
7. H. L. Grubin and H. L. Cui, "Spin Dependent Transport in Quantum and Classically Configured Devices," Int. J High Speed Electronics and Systems, 16, 639 (2006).
8. W. Zhang, D. Woolard, E. Brown, B. Gelmont and R. Trew, "Design and Optimization of an I-RTD hybrid THz Oscillator based upon In1-xGaxAs/GaSbyAs1-y Heterostructure Systems," Proceedings of 2006 ISSSR – to be published as a special issue of the Int. J High Speed Electronics and Systems (2006).
9. H. L. Grubin, "Spin Dependent Wigner function Simulations of Diluted Magnetic Semiconductor Superlattices – B Field Tuning. Proceedings of 2006 ISSSR – to be published as a special issue of the Int. J High Speed Electronics and Systems (2006).
10. M. Kohda, T. Kita, Y. Ohno, F. Matsukara and H. Ohno, "Bias Voltage Dependence of the Electron Spin Injection Studied in a Three Terminal Device Based on a (Ga,Mn)As/n+ -GaAs Esaki Diode," Applied Physics Letters, 89, 012103 (2006).
11. S. J. Pearton, D. P. Norton, R. Frazier, S. Y. Han, C. R. Abernathy and J. M. Zavada, "Spintronic Device Concepts," IEE Proceedings - Circuits, devices and Systems, 152, 312 (2005).
12. W. Yang, K. Chang, X. G. Wu and H. Z. Zheng, "Spin-Polarized Transport in a Lateral Two-Dimensional Diluted Magnetic Semiconductor Electron Gas," Applied Physics Letters, 88: p. 082107 (2006).
13. Qi, Y., Z. Yu, and M.E. Flatte, "Spin Gunn Effect," Phys. Rev. Letts, 96: p. 026602 (2006).

KEYWORDS: diluted magnetic semiconductors, spin transport, resonant tunneling devices, superlattices, terahertz frequency

A07-T023 TITLE: Modular Protein Manufacturing Platform

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: Develop modular vector constructs and/or engineer metabolic pathways and metabolons capable of enhanced protein production of high value proteins in highly stable transduced cell lines.

DESCRIPTION: The production of proteins at large-scale and low cost has enormous strategic implications which have been identified in detail by the Army's Biotechnology Integrated Products Team and studies by the Office of Net Assessment and the National Research Council. Examples include biopolymers for lightweight materials, therapeutic drugs and prophylactic vaccines, and alternative energy production such as ethanol and methanol. All biomanufacturing processes have in common the need to introduce a gene or genes, using a carrier called a vector, into the producing cell line, optimally with great efficiency and stability. The major issues in biomanufacturing are instability of the transduced cell line and low product yields, which results in a manufacturing process that is not economically viable. In some cases, the product is toxic to the host cell and the latter dies. In others, the inserted gene(s) is not stable hence not passed on to daughter cells. Most current vector constructs are inefficient and engineered metabolic pathways do not account for spatial organization, thus hindering protein production. The proposed vector system should be modular to accommodate a variety of genes, gene inhibitory sequences, promoters and secondary genes. Secondary genes, which include anti-apoptotic, growth promoting and drug resistant genes, are inserted to increase production yields. Transduction should result in the creation of a stable cell line whereby the vector construct is stably integrated into the host cell at high copy numbers. In addition, engineering metabolic pathways with consideration for spatial organization and construction of metabolons is also a major issue in optimizing yields.

PHASE I: (Feasibility Study) Identify a vector system and demonstrate stable insertion of genes at high copy number in a host of cell line. Modularity must be demonstrated by stable insertion of a number of secondary genes.

PHASE II: (Prototype Delivery) Select a low performing cell line producing a protein of high value to the DoD. Examples would be a hybridoma cell line producing an antibody against a list A pathogen, or a cell line producing a therapeutic or prophylactic protein, but are not limited to these. Using different combinations of primary and secondary genes, as well as strategies to spatially organize metabolic pathways and metabolons, demonstrate enhanced yields of the protein as well as long-term stability of the transduced cell line. Conduct economic assessment of the transduced verses original cell line.

PHASE III: The resulting Protein Manufacturing Platform could be applied to the production of any protein, but will have its greatest strategic and economic impact on the manufacture of high value, low yield proteins. Accordingly, it will have markets in both the pharmaceutical and biotechnology industries, in addition to the Army's biotechnology programs and the DoD's Critical Reagents Program.

REFERENCES:
1. Cane, D.E., Walsh, C.T. and Khosla, C. Harnessing the biosynthetic code: combinations, permutations and mutations. Science 1998, 282, 63-68.

2. de Boer, A.L. and Schmidt-Dannert, C. Recent efforts in engineering microbial cells to produce new chemical compounds. Current Opinions Chem. Biol. 2003, 7, 273-278.

3. Desai, S.K. and Gallivan, J.P. Genetic screens and selections for small molecules based on a synthetic riboswitch that activates protein translation. J. Am. Chem. Soc. 2004, 126, 13247-13254.

4. Jorgensen, K., Rasmussen, A.V., Morcent, M., Nielsen, A.H., Bjarnholt, N., Zagrobelny, M., Bak, S., and Moller, B.L. Metabolon formation and metabolic channeling in the biosyntheses of plant natural products. Current Opinions Plant Biol. 2005, 8, 280-291.

5. Schmidt-Dannert, C. Directed evolution of single proteins, metabolic pathways and viruses. Biochemistry. 2001, 40, 13125-13136.

6. Schonley, K., Afable, C., Slepushkin, V., Lu, X., Andre, K., Boehmer, J., Bengston, K., Doub, M., Cohen, R., Berlinger, D., Slepushkina, T., Chen, Z., Li, Y., Binder, G., Davis, B., Humeau, L and Dropublic, B. QC Release testing of an HIV-1 based lentiviral vector lot and transduced cellular product. Bioprocessing Journal 2003, 2(4), 39-47.

KEYWORDS: Biomanufacturing, metabolic engineering, genetic vectors, metabolons, genetic engineering

A07-T024 TITLE: <u>Aerosolization of Densified Powders Using Sublimable Solids</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The main objective is to identify processes to mix solutions of sublimable materials with metal flake powders and then dry these slurries with the dual goal of metal flake powder deagglomeration and densification for efficient volume limited transport and subsequent aerosolization using heat and airflow or explosive or pneumatic grenade. To measure the performance of the dried packed metal nanoflakes, the extinction coefficient will be measured in the ECBC smoke test chamber.

DESCRIPTION: Fine pigment grade metal flake powders have relatively low bulk densities in dry form and can be densified by dispersing them into a liquid to form slurries and then drying the slurries to reduce interparticle spacing. However agglomeration problems arise when attempting to aerosolize densified dry powders as individual metal flakes even if the dispersion process is effective at deagglomerating the particles in the liquid slurry. It is expected that this difficulty can be avoided by dissolving an optimal amount of sublimable solid into a liquid and then dispersing the fine metal flake powder into this solution. A continuous sublimable solid phase containing metal flakes can then be produced by drying the slurry and the powder interparticle spacing will be minimized and the flakes will be deagglomerated. The sublimable solid matrix can be directly converted to gas using heat and a deagglomerated aerosol containing single metal flakes will be produced by a combination of heat and air turbulence.

PHASE I: Prepare 50-100 gram quantities of dried fine pigment grade metal flake in a sublimable solid matrix and test the performance of the material developed to produce an aerosol in the ECBC smoke test chamber. The goals would be to densify the metal flake powder and aerosolize a large fraction of that powder as single flakes little altered with respect to their original size and shape.

PHASE II: Perform additional testing as in Phase I, scale-up the process to prepare dried slurries, increase single metal flake aerosol fraction and reduce cost.

PHASE III: This technology is unique and several patents may arise from this endeavor. The military has a need for this type of technology, which can be used in smoke generating pyrotechnics and smoke generators. Medical applications would utilize this technology such as in aerosol powders for inhalers and to increase surface area for improved delivery and effectiveness of medicine.

REFERENCES:
1. Silvia A. Alconchel, Materials Science and Engineering B, April 1996
2. Xuesong Lu et al, Journal of Physics D: Applied Physics 39, Studies on ultrasonic microfeeding of fine powders, 2006

KEYWORDS: Sublimable, obscurant, nanoparticle, infrared

A07-T025 TITLE: Passive Detection and Prediction of Degradation in Critical Utility Pipeline Infrastructure

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To enable severe corrosion and degradation in critical utility pipeline systems to be economically detected and predicted without human action or intervention, before a catastrophic failure occurs.

DESCRIPTION: The recent failures in petroleum pipelines serving Prudhoe Bay, Alaska have brought national attention to the problem of undetected corrosion of utility piping. As evidenced by this situation, it is possible for severe corrosion and degradation of fuel, natural gas, and water pipes to remain undetected until a catastrophic failure occurs.

The aging critical infrastructure systems at Army installations suffer from the same corrosion problems as those in the private sector. Failure of fuel, natural gas, or water piping can delay or otherwise impact the military mission, and create life safety hazards for soldiers and their families. In addition, failure to take corrective action before a critical infrastructure component has become irreparably damaged and/or environmental contamination has occurred violates the principles of sustainability. Congress and the Department of Defense have recognized that corrosion has a detrimental impact on military readiness and have instituted a DoD-level Corrosion Prevention and Control Program to help address it (PL 107-314, Section 1067; DoD Policy Memorandum 2003).

Pipe inspections using existing technology ("smart pigs", ultrasound, acoustic emission, etc.) require funding and human action each time an inspection is to be executed. Severe budget cuts have made the funding and staffing of such inspections nearly impossible. Furthermore, the inspection provides one-time results and cannot accurately predict when a pipe will actually fail. Thus, accurate planning for critical Army infrastructure rehabilitation or replacement is nearly impossible given the current technology and budgetary limitations.

It is believed that recent advances in sensor technology (including nanotechnology), secure wireless networking, and analytic techniques such as neural networks can be brought together to feasibly and economically solve this problem (Carnegie Mellon University 2006; Mounce and Machell 2006; Olariu et al. 2004).

PHASE I: Develop an economical corrosion detection and prediction system that is designed for permanent installation in a fuel or water piping network. The system should continuously monitor the pipeline for corrosion damage, without requiring human action or intervention. Secure wireless solutions are encouraged. The system should then be able to accurately and reliably predict when a pipe failure is expected so that repair and replacement programs can be developed in a timely fashion. Phase I work should focus on proof-of-concept.

PHASE II: Develop a field-deployable prototype corrosion detection and prediction system based upon the findings of Phase I. Demonstrate and validate the system on a critical fuel or water network at an Army installation.

PHASE III: In addition to DoD installations, this system could be used by petroleum exploration, transmission, & distribution companies (such as British Petroleum [BP], the owner of the leaking Alaskan pipeline). It could also be used by a public and private utilities involved in water and/or natural gas transmission and distribution.

REFERENCES:
1. Public Law (PL) 107-314, Bob Stump National Defense Authorization Act for Fiscal Year 2003, Section 1067 (2 Dec 2002).

2. DoD Policy Memorandum, Corrosion Prevention and Control, Undersecretary of Defense for Acquisition, Technology, and Logistics, Washington, DC, 12 Nov 2003 (available at http://www.dodcorrosionexchange.org).

3. Carnegie-Mellon University, Carnegie Mellon Researchers Launch New Center to Deliver 'Nervous Systems' for Critical Infrastructures, Press Release, 1 March 2006 (available at http://www.cmu.edu/PR/press_releases/index.html)

4. Stephen R. Mounce and John Machell, Burst Detection Using Hydraulic Data from Water Distribution Systems with Artificial Neural Networks", Urban Water Journal, vol. 3, no. 1, March 2006.

5. Stephen Olariu, Ashraf Wada, Larry Wilson, and Mohammed Eltoweissy, Wireless Sensor Networks: Leveraging the Virtual Infrastructure, IEEE Network, July/August 2004.

KEYWORDS: sensors, corrosion, failure prediction, pipelines, utility systems, critical infrastructure

A07-T026 TITLE: Statistical Mobility Prediction for Small Unmanned Ground Vehicles

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: To develop innovative methods and software for quickly and robustly predicting the ability of small robotic unmanned ground vehicles (UGVs) to successfully surmount obstacles in challenging environments. The method will employ physical models of vehicle multibody dynamics and vehicle-terrain interaction in a novel, efficient statistical simulation framework to yield an accurate assessment of UGV mobility in both cross-country and urban scenarios, despite uncertainty in terrain physical properties. The software tool to be developed will allow small UGVs to accurately and autonomously predict their mobility over a wide range of conditions, a capability which is critical to Future Combat Systems (FCS) robotics missions.

DESCRIPTION: The Army has devoted significant resources to understanding and predicting the mobility of military vehicles in natural terrain. Research and field testing at the USA Engineer Research and Development Center (ERDC) over the past 50 years has led to development of various mobility prediction methodologies including the NATO Reference Mobility Model (NRMM), NRMM II, and others [1-3]. These are physics-based numerical algorithms for predicting cross-country vehicle movement at length scales of several meters to several kilometers. These methods were developed for vehicles of 500 kg and larger and have been proven to be accurate over a wide range of conditions.

Future Army operations under the FCS paradigm will employ small (i.e. sub-500 kg) autonomous or semi-autonomous UGVs in both cross-country and urban environments. A fundamental requirement of these UGVs is to quickly and robustly predict their ability to successfully negotiate terrain regions and surmount obstacles. The obstacles may be natural or man-made, and may be positive or negative (i.e. projecting above or below the nominal ground plane). This mobility prediction capability is critical to successful deployment of UGVs that can operate effectively in challenging terrain with minimal or no human supervision.

Efforts are currently underway to extend "classical" NRMM methodologies to small UGV platforms, with promising results [4]. However, these efforts assume accurate knowledge of vehicle-terrain interaction properties, gathered from terrain measurement devices such as cone penetrometers. In field conditions, UGVs will often only have access to sparse and uncertain terrain condition estimates. Therefore, development of a method for robustly predicting UGV mobility despite uncertainty in terrain conditions is desired.

There exists a wide body of literature on statistical simulation for estimating output probability distributions of processes that are subject to uncertainty [5-6]. Such techniques could be applied to the mobility prediction problem by modeling the distributions of unknown vehicle-terrain parameters and analyzing the performance of a physics-based UGV model over that parameter space [7]. However, these methods can be computationally expensive if the parameter space is high dimensional or the underlying model is nonlinear and/or possesses many degrees of freedom. A central research question to be addressed in this topic lies in developing innovative, efficient methods for statistical model-based mobility prediction despite high dimensional parameter spaces and complex vehicle models.

The proposed effort is critical to the development of autonomous UGVs that will operate reliably in challenging environments. Successful development of a real-time mobility prediction capability would result in increased survivability, reliability and mission effectiveness in all terrain conditions during both autonomous and semi-autonomous UGV operation.

PHASE I: Work in Phase I would involve investigation and feasibility demonstration of a method(s) for robust statistical mobility prediction for small UGVs. In addition to identifying promising computational techniques, this would involve identifying relevant vehicle-terrain interaction parameters and developing models for their distributions, and identifying appropriate levels of complexity of physics-based vehicle models. Another component of Phase I research would involve initial development of a mobility prediction/visualization tool of an Army-relevant UGV operating in cross-country or urban terrain. The result of Phase I will be a proof-of-concept simulation demonstration of a mobility prediction algorithm operating on an Army-relevant system. An example might be prediction of a small (i.e. 100 kg-class) UGV surmounting gaps of varying width.

PHASE II: Phase II would focus on improving the computational efficiency of the statistical mobility prediction algorithm developed in Phase I. Methods for efficient sampling of parameter distributions would be investigated. Work would also focus on development of an integrated mobility prediction/visualization software tool for a relevant Army platform. The platform may be wheeled or tracked and would be selected in coordination with Army personnel. The software would analyze synthetic sensor data (i.e. laser-based, vision, etc.) to extract information about a simulated terrain region, and use the statistical mobility prediction method to efficiently predict obstacle traversability in both cross-country and urban scenarios.

PHASE III: Work in Phase III would focus on collaborating with Army personnel to transition the mobility prediction software to an Army-relevant UGV platform for operational testing. The mobility prediction software would be integrated with on-board UGV sensors and an accurate physics-based model of the UGV platform. The software would be tested in a variety of scenarios in various environmental conditions to evaluate its accuracy and robustness. Successful commercialization will require development of a Joint Architecture for Unmanned Systems (JAUS)-compatible "plug-and-play" vehicle/sensor modeling method.

The proposed software could also be applied to civilian mobile robotics applications that require robust terrain analysis, navigation, and mobility prediction. These include hazardous site inspection/clean up, search and rescue, and tasks in the forestry and mining industries.

REFERENCES:
1. Rula, A, and Nuttall, C., An Analysis of Ground Mobility Models (ANAMOB), Technical Report M-71-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS, 1971
2. Jurkat, M., Nuttall, C., and Haley, P., The AMC '74 Mobility Model, Technical Report 11921, US Army Tank Automotive Command, Warren, MI, 1975
3. Willoughby, W., Jones, R., Mason, G., Shoop, S., and Lever, J., "Application of Historical Mobility Testing to Sensor-Based Robotic Mobility Performance," Proceedings of the SPIE Conference on Unmanned Systems Technology VIII, 2006
4. Introduction to Monte Carlo Methods, http://www.ipp.mpg.de/de/for/bereiche/stellarator/Comp_sci/CompScience/csep/csep1.phy.ornl.gov/mc/mc.html
5. Johnson, M., Multivariate Statistical Simulation: A Guide to Selecting and Generating Continuous Multivariate Distributions, Wiley, 1987
6. Golda, D., Iagnemma, K., and Dubowsky, S ., "Probabilistic Modeling and Analysis of High-Speed Rough-Terrain Mobile Robots," Proceedings of the IEEE International Conference on Robotics and Automation, 2004

KEYWORDS: Mobility, unmanned ground vehicles, vehicle-terrain interaction, vehicle modeling

A07-T027 TITLE: Terrain Analysis from Unmanned Ground Vehicle Sensors

TECHNOLOGY AREAS: Ground/Sea Vehicles

OBJECTIVE: To develop innovative methods and software for analyzing data from sensors present on unmanned ground vehicles (UGVs) to estimate physical properties of local terrain. Creative approaches to terrain characterization are required that exploit both range sensor data and proprioceptive sensor data. The software tool to be developed will allow UGVs to accurately and autonomously assess the physical nature of the surrounding terrain, which will lead to significant improvement in navigation and mobility prediction capabilities.

DESCRIPTION: The Army Future Combat Systems (FCS) initiative relies heavily on UGVs to perform a variety of autonomous and semi-autonomous tasks [1]. These tasks will require armed and unarmed UGVs to travel through diverse environments, including cross-country and urban terrain. A key enabling element of UGV mobility is terrain perception, and several Department of Defense (DoD) research programs have focused on robust multi-sensor terrain perception, including the Army DEMO III program and the DARPA PerceptOr program [2-4]. Robust terrain perception will allow a UGV to reason about the elevation, composition, and physical properties of local terrain, and thereby perform accurate mobility prediction.

The vast majority of previous work in autonomous terrain perception has focused on processing of data from range sensors that are mounted on board the UGV. These include stereo vision systems, laser-based range sensors, radar, and other modalities [3,5]. A fundamental limitation of these approaches is that they provide information about the terrain surface layer, which may not be the load bearing layer. In addition, it is difficult to infer terrain physical properties related to deformability and motion resistance from range sensor data. Recent research has proposed techniques for classifying terrain via proprioceptive sensor data arising from physical vehicle-terrain interaction [6]. Such approaches promise to yield information about physical terrain properties, and thus are likely to be a useful complement to approaches that exploit data from range sensors.

The goal of this effort is to develop methods and software for terrain analysis that exploit both range sensor data and proprioceptive sensor data in a unified framework, and thereby provide estimates of the physical properties of local terrain that can be used to improve mobility prediction. Here "range sensor" refers to on-board UGV sensors that detect features located in the local environment (i.e. 1m - 100m range) of the vehicle. Such sensors include monocular and stereo vision systems, LIDAR sensors, RADAR sensors, and others. "Proprioceptive sensor" refers to on-board UGV sensors that detect features related to motion of the vehicle. Such sensors include wheel position, velocity and torque sensors, suspension displacement sensors, chassis vibration sensors, accelerometers, rate gyroscopes, and others. A baseline sensor suite has not been defined for this effort, and proposers are encouraged to consider creative sensing modalities that could yield novel and useful data products for mobility prediction.

The methods and software developed in this work would yield estimates of the physical properties of local terrain that would be used for accurate mobility prediction. These estimates may be in the form of physical parameter estimates (i.e. estimates of soil cohesion, internal friction angle, cone index value, etc.), and/or a novel metric(s) related to vehicle mobility. Proposed approaches should explicitly describe how their resulting data products would be used for UGV mobility prediction. Practical issues related to computational efficiency and sensitivity to environmental conditions should be addressed in this work. Software developed as a product of this work should quickly, accurately and autonomously assess the physical nature of the terrain surrounding an Army-relevant UGV platform.

PHASE I: Work in Phase I would involve investigation and identification of methods for terrain analysis that exploit both range sensors and proprioceptive sensors in a unified framework. Candidate methods and techniques could be drawn from the domains of pattern classification, signal processing, parameter estimation, and data fusion. Novel analysis methods in any of these domains are encouraged. An analysis of algorithm sensitivity/error modes is also required. Other work in Phase I would outline a pathway for using the proposed data products for UGV mobility prediction. The result of Phase I will be a proof-of-concept demonstration of the terrain analysis method operating on data gathered from either an experimental UGV testbed (or mockup) in outdoor conditions, or a high-fidelity simulation environment.

PHASE II: In Phase II a robust, real-time implementation of the terrain analysis method would be implemented on a UGV testbed operating in harsh, real-world conditions. The testbed can be a small COTS platform or a larger, custom-built vehicle. The possibility of implementing the proposed software on an Army vehicle testbed with appropriate sensors for data collection would also be investigated. Emphasis in Phase II will be on experimental analysis of algorithm performance under a variety of challenging environmental conditions. Methods for improving computational efficiency and algorithm robustness will also be investigated.

PHASE III DUAL USE APPLICATIONS: Phase III would focus on collaborating with Army personnel to transition the terrain analysis software to an Army-relevant UGV platform for operational testing. The terrain analysis software would be integrated with on-board UGV sensors and the software would be tested in a variety of scenarios in various environmental conditions to evaluate its accuracy and robustness. Successful commercialization will require development of a Joint Architecture for Unmanned Systems (JAUS)-compatible "plug-and-play" vehicle/sensor modeling method.

The proposed software could also be applied to civilian mobile robotics applications that require robust terrain analysis, navigation, and mobility prediction. These include hazardous site inspection/clean up, search and rescue, and tasks in the forestry and mining industries.

REFERENCES:
1. Army Future Combat Systems description, http://www.army.mil/fcs/
2. C. Shoemaker and J. Bornstein, "The Demo III UGV Program: A Testbed for Autonomous Navigation Research," Proceedings of the IEEE International Conference on Intelligent Control, 1998
3. A. Kelly, A. Stentz, O. Amidi, M. Bode, D. Bradley, A. Diaz-Calderon, M. Happold, H. Herman, R. Mandelbaum, T. Pilarski, P. Rander, S. Thayer, N. Vallidis, and R. Warner, "Toward Reliable Off Road Autonomous Vehicles Operating in Challenging Environments," The International Journal of Robotics Research, Vol 25, No 5/6, 2006
4. http://www.darpa.mil/tto/programs/fcs_ugcv.htm
5. P. Bellutta, R. Manduchi, L Matthies, K. Owens, A. Rankin, "Terrain Perception for DEMO III," Proceedings of the Intelligent Vehicle Symposium, 2000
6. C. Brooks and K. Iagnemma, "Vibration-based Terrain Classification for Planetary Rovers," IEEE Transactions on Robotics, Vol 21, No 6, pp. 1185-1191, 2005

KEYWORDS: Sensing, unmanned ground vehicles, mobility, vehicle-terrain interaction

A07-T028 TITLE: Reduced-Order High-Fidelity Models for Signature Propagation

TECHNOLOGY AREAS: Battlespace

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: This research will develop a method for reduced-order modeling of large dynamic seismic and acoustic systems, capable of reproducing results of high-fidelity high-performance numerical computations in real-time or near-real-time calculations. The focus will be on wave-propagation computations requiring a terrestrial-surface boundary condition, and thus the objective is a highly efficient means to calculate near-ground-level signature propagation. The method will be relevant to propagation computations in complex open or urban terrain—at scales compatible with source and sensor locations of military interest—and will be transferable to applied seismic and acoustic modeling and propagation physics such as electromagnetism.

DESCRIPTION: Only 3D high-fidelity computations, performed on massively parallel supercomputers, can simulate signal propagation in geometrically complex large-scale environments, such as urban areas and areas with complex terrain, without excessively compromising realism. These computations are thus impossible for DoD applications such as urban semi-automated-forces and decision-support simulations that must be performed on single-processor or small multi-processor computers at the brigade level.

Impulse response functions of a propagation wavefield contain all energy in its bandwidth that reaches an output location from an input location, and superposition provides that a system's response to any arbitrary input can be calculated from a linear combination of the impulse responses of that system, so well-constructed state-space realizations of the wavefield will be complete from the perspective of multi-path arrivals and other complex propagation phenomena. The impulse-response simulations are currently performed on high-performance computers. These simulation of the seismic and acoustic signal propagation are done using a finite-difference time-domain approach, as are computationally intensive, taking up to 256 processors, many tens of gigabytes of memory, and hours to run. The simulations can be of urban areas with complex terrain, and accurately simulate the signal propagation up to 100 hertz.

A method is needed which can reduce the impulse-response function system information to a signal localization method based on the number and placement of seismic or acoustic sensors.

PHASE I: The desired results of the Phase I work will be a research-grade code which shows how the results from a detailed simulation of an area 1 km square accurate up to 100 Hz, performed on a high-performance computer, can be reduced to a problem appropriate for a single CPU computer with 1 GByte of memory. The reduced-order model must provide decision-aid tools for choosing sensor locations and for predicting sensor performance.

PHASE II: (Prototype Delivery) The desired results for Phase II work will be a commercial-grade code with training materials that can be used by trained soldiers as guidelines for placing sensors and understanding the expected sensor performance.

PHASE III: Commercialization includes both military & civilian applications. The commercial product is expected to be a turnkey sensor network ready for deployment. The user would need to provide geospatial information and the installation software would indicate sensor placement and predict sensor performance. Wireless acoustic and seismic sensor networks easily and intelligently deployed can provide information about threat identification and tracking which is useful for military installations and law enforcement. This can reduce personnel cost for perimeter monitoring, while providing accurate and useful knowledge of the types of threats that may be underway. This would likely be used by law-enforcement agencies for border security, by commercial companies responsible for large outdoor areas or large buildings for safety or security purposes. For example, if the Long Beach Port Authority needs to ensure that all people have left a particular area during holidays, knowing where to place a turnkey sensor network ready for deployment would be a cost-effective approach. Similarly, the perimeters of large Army installations can be monitored more effectively with fewer personnel.

REFERENCES:
1. Chen, J. and Hall, S.B. (2006). An efficient wave propagation model for simulation and analysis of multipath effects, http://www.moutfact.army.mil/UO_Summit_V.htm.
2. Juang, J.N. (1994). Applied System Identification. Saddle River, NJ: Prentice Hall.
3. Lucia, D.J. Beran, P.S., and Silva, W.A. (2004). Reduced-order modeling: new approaches for computational physics, Prog. in Aerospace Sci. 40:51-117.
4. Gaitonde, A.L. and Jones, D.P. (2003). Reduced order state-space models from the pulse responses of a linearized CFD scheme. Int. J. Numer. Meth. Fluids. 42:581–606
5. Yan, J., Chuhan, Z., and Feng, J. (2003). A coupling procedure of FE and SBFE for soil-structure interaction in the time domain. Int. J. Numer. Meth. Eng. 59:1453–1471.
6. Ketcham, S., Moran, M., Lacombe, J., Greenfield, R., and Anderson, T. (2005). Seismic source model for moving vehicles, Trns. Geosc. Rem.Sens., IEEE. 43:248-256.
7. Ho, B.L., and Kalman, R.E. (1966). Effective construction of linear state-variable models from input/output functions. Regelungstechnik. 14:545-548.
8. Chen, C. T. (1998), Linear System Theory and Design, 3rd ed., Oxford University Press
9. Moore, B. C. (1981). Principal component analysis in linear systems: controllability, observability, and model reduction. Trns. Auto. Cntrl., IEEE. AC-26:17-31.
10. Juang, J.N., and Pappa, R.S. (1985). An eigensystem realization algorithm for modal parameter identification and model reduction. J. Guid., Contr. Dyn. 8:620-627.
11. Juang, J. N., and Pappa, R. S. (1986). Effects of noise on modal parameters identified by the eigensystem realization algorithm. J. Guid., Contr. Dyn. 9:294-303.
12. Ketcham, S., Lacombe, J., Anderson, T., and Moran, M. (2005). Seismic propagation from humans in open and urban terrain. Proc. 2005 Users Group Conf., DoD High Performance Computing Modernization Program, IEEE Comp. Soc., 270-277.
13. Dey, S., and Datta, D. K. (2005). A parallel hp-fem infrastructure for three-dimensional structural acoustics. Int. J. of Num. Meth. Eng. (in review).

KEYWORDS: Battlespace awareness, reduced-order modeling, acoustic sensing, seismic sensing, computational methods

A07-T029 TITLE: Development of an Advanced Comfortable Prosthetic Socket

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Design and prototype a comfortable, inexpensive, yet rugged prosthetic socket which adapts itself to the residual limb in a timely fashion. This new socket will provide an ultimate fit and an improvement in the performance of the prosthesis by adapting to every change that occurs in the residual limb.

DESCRIPTION: With the arrival of new body armor technology and the continuation of the Global War on Terrorism there are more survivors and an increase in the military amputee population. The volume of the residual limb of an amputee changes throughout the course of a day and/or throughout the year. These changes can be caused by different phenomena like physical activities, thermoregulation, heterotopic ossification, complex skin grafts, etc. Such changes make the interface between the socket and the residual limb inadequate, creating significant discomfort that may lead to the eventual rejection of the prosthesis by the amputee. The demands and requirements of the amputee population have increased. These new requirements leave no place for an uncomfortable or non-performing socket/residual limb interface. This new socket should provide ultimate fit and an improvement in the performance of the prosthesis. The socket should be adapting itself to the new physical shape of the residual limb and at the same time stay in perfect alignment and relation with the prosthesis. This topic is open for technology that would allow for a real time adaptation. Any energy source employed should be lightweight and long lasting. Use of lightweight, breathable, and ultrasound transparent material is strongly encouraged. The new device should be able to function in a variety of environments including cold and heat, and water or sand for example. For this topic the socket maybe for an upper or lower limb but the concept should be transposable to any kind of amputation.

PHASE I: 1) Plan and design based on existing data a socket that can adapts to any change in the configuration of the residual limb. 2) Plan and design based on existing data a socket/prosthesis interface. 3) Plan and design based on existing data an energy sources to allow the device to perform in a long lasting manner.

PHASE II: Develop and demonstrate a prototype system that can, in real time, adapt itself to an exercising residual limb. The prototype should use a form of energy that can supply enough energy to test the device for a period of five days on a mock residual limb.

PHASE III: Collaborate with the topic authors in transitioning the prototype to operational testing and to marketable product that would be readily available for the combat troop. Once the transition has been achieved the new improved prosthetic/socket will be made available to our soldier that want to go back to their challenging regular activities including return to combat. Because of this new prosthetic/socket system the performance of the already existing prosthetic device will be greatly improved. This device will also eventually be useful for all the civilian population that undergoes limb amputation. Diabetic patients are the biggest part of this civilian population.

REFERENCES:
1. Seelen HA, Anemaat S, Janssen HM, Deckers JH. Effects of prosthesis alignment on pressure distribution at the stump/socket interface in transtibial amputees during unsupported stance and gait. Clin Rehabil. 2003 Nov;17(7):787-96.

2. Fang CH., Huang MJ., Chou YL., and Huang GF., The study of thermal comfort for below the knee prosthesis. Biomed Eng Appl Basis Comm, 2004 Feb; 16:7-14

3. Goh JC, Lee PV, Chong SY. Comparative study between patellar-tendon-bearing and pressure cast prosthetic sockets.J Rehabil Res Dev. 2004 May;41(3B):491-501.
4. Jia X, Zhang M, Li X, Lee WC. A quasi-dynamic nonlinear finite element model to investigate prosthetic interface stresses during walking for trans-tibial amputees. Clin Biomech (Bristol, Avon). 2005 Jul;20(6):630-5.

5. Sanders JE, Zachariah SG, Jacobsen AK, Fergason JR. Changes in interface pressures and shear stresses over time on trans-tibial amputee subjects ambulating with prosthetic limbs: comparison of diurnal and six-month differences.J Biomech. 2005 Aug;38(8):1566-73.

6. Faustini MC, Neptune RR, Crawford RH. The quasi-static response of compliant prosthetic sockets for transtibial amputees using finite element methods.Med Eng Phys. 2006 Mar;28(2):114-21.

7. Isozaki K, Hosoda M, Masuda T, Morita S.CAD/CAM evaluation of the fit of trans-tibial sockets for trans-tibial amputation stumps. J Med Dent Sci. 2006 Mar;53(1):51-6.

8. Carroll K.Lower extremity socket design and suspension. Phys Med Rehabil Clin N Am. 2006 Feb;17(1):31-48.

KEYWORDS: Prostheses, Military Amputees Performances, Prosthtic Socket, Residual Limb

A07-T030 TITLE: Chromatophore-Based Toxicity Sensor for Water

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: The objective is to develop a chromatophore cell-based toxicity sensor that responds rapidly upon exposure to toxic chemicals by producing a signal suitable for automated monitoring. Advances in this area will provide a technique to enhance the operation of the Environmental Sentinel Biomonitor (ESB) system being developed by the U.S. Army Center for Environmental Health Research (USACEHR) to rapidly identify potential health effects on deployed forces resulting from water-borne exposures to a wide array of toxic chemicals.

DESCRIPTION: As part of a research program to identify environmental hazards to soldiers resulting from exposure to toxic industrial chemicals, USACEHR is seeking new methods for providing rapid toxicity evaluation of water samples. Although several investigators have demonstrated the potential for using chromatophore-based sensors for monitoring water quality as well as in drug development (Dierksen et al. 2004; Karlsson et al., 2002), a usable device that overcomes associated technical challenges has yet to be developed. We are seeking innovative and creative research and development approaches that take advantage of recent advances in cellular and molecular biology, materials science, and image technology to provide an efficient, rapid chromatophore-based screening tool for toxicity in water samples.

PHASE I: Conduct research to provide a proof of concept demonstration of a chromatophore cell-based toxicity sensor technique for water. The concept will be original or will represent significant extensions, applications, or improvements over published approaches. Design and performance considerations for a proof of concept demonstration are listed below.

1. The endpoint(s) selected must be responsive to toxicity induced by different modes of toxic action representative of industrial chemicals of military concern, including those for which Military Exposure Guidelines (MEGs) have been developed (USACHPPM, 2004). Endpoint responsiveness should be demonstrated with five of the MEG chemicals used for toxicity sensor evaluation by van der Schalie et al. (2006); appropriate sensitivity will be evaluated with respect to the corresponding 7-14 day MEG concentration for water. Appropriate sensitivity to neurotoxicants is particularly desirable.
2. Variability in the statistically-derived test endpoint should be minimized; a coefficient of variation for the endpoint in repeated independent tests should be 15% or less.
3. Responses by the endpoint(s) monitored must occur within an hour of the initiation of toxicant exposure.
4. Endpoint(s) that require minimal preparation and processing steps and that can be easily and rapidly monitored and evaluated with automated technology are preferred, as are approaches with a potential for increased storage time of the cell-based system prior to use (30 days or more).

PHASE II: Expand upon the Phase I proof of concept effort to develop a prototype toxicity sensor that can be integrated with the USACEHR ESB system. Demonstrate sensor sensitivity (with respect to the 7-14 day MEG concentration for water) and rapidity of response (within an hour) to each of the chemicals tested by van der Schalie et al. (2006). The sensor should be designed for straightforward data interpretation, minimal logistical requirements, and maximum storage time of biological components and reagents (if any) prior to use. Demonstrate that the sensor has a low false positive rate in water matrices typical of Army field water supplies.

PHASE III: Evaluate the ability of the toxicity sensor technique to assess the suitability of drinking water for deployed troops under field conditions to enhance the capabilities of the USACEHR ESB system. Field tests will involve testing at Army water production facilities. Given current on-going concerns regarding accidental or intentional contamination of water supplies, this technology will have broad application for water utilities as well as state and local governments. In addition, the toxicity evaluation technique should be broadly usable for high-throughput screening of pharmaceutical products for efficacy and toxicity. A well-formulated marketing strategy will be critical for success in these commercial applications.

REFERENCES:

1. Chaplen F, Upson RH, McFadden PN, Kolodziej W. 2002. Fish chromatophores as cytosensors in a microscale device: detection of environmental toxins and bacterial pathogens. Pigment Cell Res 15:19-26.

2. Dierksen KP, Mojovic L, Caldwell BA, Preston RR, Upson RH, Lawrence JR, McFadden PN, Trempy JE. 2004. Responses of fish chromatophore-based cytosensor to a broad range of biological agents. Journal of Applied Toxicology 24:363-369.

3. U.S. Army Center for Health Promotion and Preventive Medicine. 2003. Chemical Exposure Guidelines for Deployed Military Personnel. TG-230. U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD. (http://chppm-www.apgea.army.mil/documents/TG/TECHGUID/TG230.pdf)

4. van der Schalie WH, James RR, Gargan TP, II. 2006. Selection of a battery of rapid toxicity sensors for drinking water evaluation. Biosensors and Bioelectronics 22:18-27.

KEYWORDS: rapid toxicity identification, toxicity sensor, chromatophore, toxicity indicator, toxic industrial chemicals, drinking water

A07-T031 TITLE: Development of Virtual Reality Tools for Training and Rehabilitation of Patient Using Advanced Prosthesis

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Design and prototype a virtual reality tool to be used in the training and rehabilitation of military amputees. This new virtual tool will help to improve and accelerate the rehabilitation of servicemembers, allowing them to return as soon as possible to high-level activities such as active duty, sports, or even extreme activities such as rock-climbing, mountain-biking, skiing, etc.

DESCRIPTION: With the arrival and enforced utilization of new body armor technology and the continuation of the Global War on Terrorism there are more survivors of severe battlefield trauma resulting in a relative increase in the military amputee population. Virtual Reality (VR) technologies have been used to help patients overcome phobias, manage pain and improve relaxation skills. VR is also used to train servicemembers for deployment. It is well know that rehabilitation for amputees is difficult since many patients rapidly become uninterested in tasks perceived as unrealistic. Virtual Reality will help to render these tasks as realistic, and the rehabilitation challenging, fun, and appropriate for the patient's skill level. Although virtual reality is being used in many areas of medicine, the realism, or suspension of disbelief, must be greatly improved to increase efficacy. Therefore, this topic aims to produce a Virtual Reality environment in which the patient would feel fully immersed. In this project, the principal investigator will design a program that will serve a range of patient abilities, from those just beginning to use their new prostheses to those who may be preparing for deployment or a return to civilian life. This system should also be designed to help amputees who would use electromyography or new surgical techniques to practice muscle or neural recruitment in preparation for their new prosthetic device. The new system should also allow for computer-based real time metrics of performance improvement, so that user performance can be tracked to help motivate patients to higher levels of performance. This topic is open for any advanced technology that would allow the realization of the present objective. The virtual prosthetic trainer should allow for training of both upper and lower limb prosthetic use, initially including both below and above elbow and knee amputee training with the potential to expand to any of the most common types of upper and lower extremity amputations including shoulder and hip disarticulations. The system should be able to train both mechanical and myoelectrically activated prosthetics.

PHASE I: Investigators will survey the current status of use of VR for training in the use of prosthetics. Investigators will then survey active duty occupational and physical therapists who provide care to military amputees to develop a taxonomy of measurable physical parameters used in initial patient assessments. After obtaining this baseline data set, the researchers will propose technical solutions for the efficient measurement of these ideal parameters.

PHASE II: In phase II the investigator is expected to design a prototype training system including the design of registration tools capable of registering amputees into open architecture VR toolkits to be used in conjunction with clinical Occupational Therapists and Physical therapists performing rehabilitation services.

PHASE III: In phase III the investigator will collaborate with the topic authors in transitioning the prototype to operational testing and then to a marketable product that would be readily available for both military and civilian amputee populations. Once the transition has been achieved the new Virtual reality training tools will be made available to our soldier that want to go back to their challenging regular activities including return to combat, to train rigorously with their new prosthetic devices before returning to combat. This device will also eventually be useful for all the civilian population that undergoes limb amputation. Diabetic patients are the biggest part of this civilian population.

REFERENCES:
1. Sveistrup H., Motor Rehabilitation using Virtual Reality. Journal for NeuroEngineering and Rehabilitation, 1:10, 2004.

2. Wiederhold BK, Wiederhold MD. The future of cybertherapy: improved options with advanced technologies. Stud Health Technol Inform. 2004;99:263-70.

3. Morie JF, Iyer K, Luigi DP, Williams J, Dozois A, Rizzo AS. Development of a data management tool for investigating multivariate space and free will experiences in virtual reality. Appl Psychophysiol Biofeedback. 2005 Sep;30(3):319-31.

4. Kuttuva m., Boian R., Merian A., Burdea G., Bouzit M., Lewis J., and Fensterheim D. The Rutgers Arm a rehabilitation system in virtual reality: a pilot study. Cyberpsychol Behav. 2006 Apr;9(2):148-51.

5. Feintuch U, Raz L, Hwang J, Josman N, Katz N, Kizony R, Rand D, Rizzo AS, Shahar M, Yongseok J, Weiss PL. Integrating haptic-tactile feedback into a video-capture-based virtual environment for rehabilitation. Cyberpsychol Behav. 2006 Apr;9(2):129-32.

KEYWORDS: Virtual Reality, Military Amputees Performances, Virtual Trainning

A07-T032 TITLE: Improved Lightweight Surgical Instrument and Linen Field Sterilization via Chlorine Dioxide or Alternative Methodology

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: We are seeking an alternative sterilization method for use in austere deployed environments. Currently steam sterilization is used to support our Combat Support Hospitals (CSH), Forward Surgical Teams (FST), veterinary and dental units.

DESCRIPTION: Steam sterilization for a deployed CSH is provided by four large steam sterilizers that are manufactured to a military specification. Each sterilizer uses 9.4 kilowatts of power, weighs 450 pounds, which requires a four-man lift, and consumes 5 gallons of water per sterilization cycle. Each cycle takes approximately one hour. If the sterilizer is used with a water recovery unit, also a military specification item, then water consumption is cut by approximately eighty percent, but power is increased by 1 kilowatt and weight by 200 pounds. In the FSTs, vet, and dental units, sterilization is additionally accomplished by a variety of tabletop steam sterilizers [all commercial-off-the-shelf (COTS) items] that average 1.4 kilowatts of power consumption, 2 gallons of water per cycle, and 40 minutes per cycle. Throughput, described as the number of instrument sets per load, varies depending on the size of the instrument sets but averages approximately 5 sets for the CSH sterilizer and 1 set for the tabletop sterilizer.

We are seeking a sterilization method that will decrease power consumption, decrease water consumption, decrease weight and cube of the units, and increase sterilization throughput in order to provide uninterrupted support for the surgical mission. Weight and cube may be possible tradeoffs for a decrease in power and water consumption.

The research community at RAD II is not currently working on any sterilization projects. US Army Medical Developmental Activity working on a peracetic acid technology but the supporting manufacturer pulled its support from the project. Plasma sterilizer projects underway look promising as they require significantly less power, but they may be unable to handle linen loads or wraps as the technology works by breaking down the cellulose within the linen. Linen wraps are used when paper is unavailable or to decrease the chance of puncture from sharp instruments. Linen packs are also sterilized and used as normal parts of the draping procedure for surgery and for positioning of the patient to achieve adequate surgical exposure.

PHASE I: Chlorine Dioxide sterilization is currently utilized to sterilize rooms and other large areas for surgical procedures and for killing of infectious organisms. We want to find out if this technology, or a similar technology, can be applied under controlled conditions to penetrate suction tube lumens and other small instrumentation channels. Compatibility of the process with materials, such as surgical grade stainless steel, fabrics and plastics, used to make surgical instrumentation and other surgical devices and appliances is required. The process must effectively render surgical instrumentation, linens and other items sterile. Sterility will be proved in accordance with standards for organism kill instituted by the American Association for Medical Instrumentation (AAMI) and the Association of periOperative Registered Nurses (AORN).

PHASE II: Phase II will culminate in the delivery of a prototype sterilizer that focuses first on the sterilization requirements of a CSH as that is the medical unit with the most labor intensive sterilization mission. The goal of this solicitation is to acquire a field deployable sterilizer or sterilizer system that will reliably operate under austere conditions. The new sterilizer should be smaller, lighter, require less power and water and be more easily maintained than the current device. The new device should at least equal the throughput of the current deployable sterilizer.

PHASE III: Possible dual use applications include utilization at both medical/dental and veterinary units for the military. It may also have applicability in the CSH and theater level labs that sterilize culture media and culture/pathogen containers. For the commercial sector, this could have applicability in free-standing surgical centers and office based practices (surgical, dental, and vet) that do not require larger, commercial size sterilizers. Their use would reduce power and water requirements and thus utility bills for those organizations.

REFERENCES:

1. AORN standards
2. AAMI standards
3. Perkins, Principles of Steam Sterilization, 1982.

KEYWORDS: surgical instruments, sterilization, chlorine dioxide

A07-T033 TITLE: <u>Novel Topical Arthropod Repellent Formulation(s) with Superior Efficacy and High User Acceptability</u>

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop novel topical arthropod repellent formulation(s) with efficacy against a wide range of disease vectors, superior duration (up to 12 hours), and high user acceptability for use by the U.S. military.

DESCRIPTION: Arthropod-borne diseases such as malaria, dengue fever, scrub typhus, and leishmaniasis pose a significant threat to U.S. military forces deployed overseas. Over 1,200 Soldiers have been infected with leishmaniasis during Operation Iraqi Freedom. Repellents are often the only means of protection against arthropod-borne diseases in combat environments when vector control measures are not possible or when the speed of military developments prevents the use of chemoprophylaxis or vaccines. In contrast to vaccines and chemoprophylaxis as means of personal protection, topical repellent use offers protection against a broad range of arthropod-borne diseases and can be applied effectively to prevent arthropod-borne disease, whether or not surveillance has identified the pathogen.

The Department of Defense previously developed the Extended Duration Topical Insect and Arthropod Repellent (EDTIAR), a DEET-based product available to military personnel for several years. To date, this is the most effective topical repellent in the military system. Although EDTIAR is an extremely effective formulation, it has several less than desirable properties, most significant of which are that it is not equally effective against all arthropod threats and users do not like the smell or feel of it on the skin. The unpleasant smell and skin feel has led to low levels of compliance among soldiers, which means they are not adequately protected against arthropod-borne disease during deployments and exercises. In response to this, the DoD provided funding (STO AU: Development of a new standard military insect repellent) to the Walter Reed Army Institute of Research from 2000-2004 to develop an improved arthropod repellent formulation. Although there are many promising new compounds currently under evaluation, to date a replacement repellent has not been developed. In light of the current operational environment, novel topical repellent formulation development is imperative.

PHASE I: Selected contractor develops a detailed plan for the development of a novel topical arthropod repellent formulation(s) that meets the following DoD requirements: 1) it must be effective (provide a minimum of 8 hours, preferably 12 hours of protection); 2) it must be effective against a wide range of arthropods; 3) it must be safe for human skin application (must be registered by the Environmental Protection Agency); and 4) it must have high user acceptability (i.e. good skin feel, acceptable odor, etc.).

PHASE II: Selected contractor tests candidate formulation(s) and demonstrates that the candidate formulation(s) meets DoD requirements. Selected contractor refines candidate formulation to address requirements for further field evaluation, including user acceptability trials and comparing the candidate formulation with EDTIAR and other commercially available formulations. The selected contractor will conduct testing of physical, chemical, and toxicological properties in accordance with EPA requirements.

PHASE III: This STTR has strong commercialization potential. Currently, there is increased interest in public health pesticides (repellents) to combat and prevent arthropod-borne diseases, such as West Nile Virus. Currently, there is a low level of compliance with the standard military topical repellent, EDTIAR, leaving troops vulnerable to arthropod-borne disease. Therefore, the military has an interest in a deliverable with superior efficacy and duration, and high user acceptability. An important step in the commercialization process is EPA registration. Under Phase III, the selected contractor will obtain EPA registration and successfully commercialize the product. Commercialization could include collaboration with a pesticide company with experience in commercialization and marketing of products for consumer usage. Additional field evaluations are conducted during Phase III for assessment of the new product for military use. This may be established through collaboration with government research laboratories by providing sufficient material for field trials. The government laboratory (ies) will provide feedback to the contractor regarding the efficacy of the formulation in repelling arthropods. Phase III would also include working with the Armed Forces Pest Management Board to obtain a National Stock Number for any repellent formulation developed that fully meets the needs and requirements of the DoD.

REFERENCES:

1. Elston, D.M. and S.D. Miller. 2004. Leishmania acquired in the Iraqi Theater of Operations: lessons learned. Cutis 74:253-255.

2. Fradin, M.S. and J.F. Day. 2002. Comparative efficacy of insect repellents against mosquito bites. New England Journal of Medicine 247(1): 13-18.

3. Gupta, R.K. and L.C. Rutledge. 1994. Role of repellents in vector control and disease prevention. American Journal of Tropical Medicine and Hygiene 50:82-86.

KEYWORDS: topical repellent, arthropod-borne disease, DEET, formulation

A07-T034 TITLE: High-Throughput Screening of Natural Product Extracts for Biologically Active Small Molecules

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: To develop a high-throughput approach using recent technological advances to rapidly screen natural product extracts (or combinatorial libraries) for novel drug leads against defined molecular malarial targets. Once this technology is developed, it would serve as a robust and efficient alternative to traditional bioassay guided fractionation and, therefore, it could be used for natural product lead discovery for any disease with a defined therapeutic molecular target.

DESCRIPTION: U.S. troops are constantly exposed to many potential infectious threats while deployed, such as viruses, bacteria, and parasites. According to the Center for Disease Control and Prevention (CDC), one of these threats – malaria – “is one of the most severe public health problems worldwide” and, therefore, as an extension should be considered one of the most severe U.S. military health problems to our deployed Warrior soldiers. Malaria has afflicted many our soldiers during our military and peacekeeping operations. In fact, the World Health Organization’s (WHO) World Malaria Report indicates that 350 to 500 million clinical malaria infections occur every year, resulting in at least one million deaths per year. Furthermore, most of these infections occur in developing countries where many of our U.S. troops serve. It is predicted that clinical infections and death will start to increase due to rapid spread of drug resistance parasites.

While the optimization of new combinations and the development of analogs of existing anti-malarial drugs offer hope in the fight against malaria, novel classes of small molecules are needed in the lead development pipeline. Secondary metabolites from natural products have long served as a rich source of drug candidates with high chemical diversity. For example, artemisinin and quinine represent potent antimalarial drugs from natural product sources. Traditionally, bioassay-guided fractionation is used to obtain lead compounds from bioactive crude extracts and intermediate fractions from numerous biological sources, including plants, fungi, and marine sponges. This process, however, is often lengthy, lasting as long as 3-6 months. De-replication of already known or "garbage" constituents from the natural product mixture is necessary. Structure elucidation is then determined on the basis of mass spectroscopy (MS), nuclear magnetic resonance, elemental analysis, and high performance liquid chromatography traces. For these reasons, the use of natural product extract libraries in high-throughput screens (HTS) has been deemphasized in the pharmaceutical industry for more "screen friendly" synthetic libraries in previous years.

Several recent publications in the scientific literature from various academic groups have demonstrated the potential power of MS when combined with various liquid chromatographic technologies as a HTS tool for the discovery of novel drug leads from complex mixtures against known molecular targets, like enzymes or cell surface receptors. The complex mixtures tested have been derived from natural product extracts or combinatorial libraries to date. Development of this technology or a completely innovative, novel technology platform with similar or better capabilities will provide a rapid, high-throughput, simplified process to discover novel drug candidates for the treatment of malaria and other infectious diseases.

PHASE I: Develop an approach for a novel high-throughput process using recent advances in MS methods or a completely different, innovative, cutting-edge technology platform with similar or better capabilities to examine uncharacterized natural product extracts for novel drug leads identification against defined molecular antimalarial targets currently being examined in our laboratory as examples. These target proteins include PfKASIII, a Plasmodium falciparum enzyme required for Type II fatty acid biosynthesis, and Pfmrk, a cyclin dependent kinase involved in P. falciparum cell cycle regulation, and other malarial enzymes.

The process developed should provide the sensitivity and selectivity necessary to identify compounds present at low concentrations in complex chemical mixtures. It should also provide a rapid prescreen of test extracts for bioactivity against purified and enzymatically active PfKASII and/or Pfmrk proteins with go/no go standards in order to filter out extracts with no target bioactivity. The bioactive extracts (those with a go status) would then be further evaluated in the developed process. This evaluation should optimally include (but not be limited to) the following information: 1) determine the mass of the lead compound in bioactive extracts; 2) possess de-replication-like capabilities linked to a database of known compounds; 3) differentiate between on-site and non-specific compound interactions with the target protein; 4) be compatible with compounds in the bioactive extracts that may bind with the target protein via noncovalent or covalent interactions; and 5) provide some structural information about the lead compound for downstream lead identification purposes.

PHASE II: Conduct proof-of-concept study that can demonstrate the ability of the developed process to detect and characterize compounds present in natural product extracts from various sources against PfKASIII, Pfmrk, and additional malarial enzymes. Validate the compounds detected through lead identification, secondary analysis of lead compound binding specificity to the target protein, and activity against the target protein in our standard in vitro enzyme assay.

PHASE III: The development and optimization of this HTS process would assist academic, industrial, and government drug discovery efforts in the pursuit of novel drug leads from natural products or combinatorial libraries. This technology would be applicable to any disease with defined molecular targets of potentially therapeutic importance (e.g. leishmania, dengue fever, numerous cancers, or even medical biological/chemical defense).

REFERENCES:
1. WHO, R. B. M. 2005. World Malaria Report 2005.

2. Rosenthal, P. J. 2003. Antimalarial drug discovery: old and new approaches. J Exp Biol 206:3735-44.

3. Koehn, F. E. and G. T. Carter. 2005. The evolving role of natural products in drug discovery. Nature Rev Drug Discovery 4:206-20.

4. Johnson, B. M., Nikolic D., and R. B. van Breemen. 2002. Applications of pulsed ultrafiltration-mass spectrometry. Mass Spectrom Rev 21:76-86.

5. Hofstadler, S. A. and K. A. Sannes-Lowery. 2006. Applications of ESI-MS in drug discovery: interrogation of noncovalent complexes. Nature Rev Drug Discovery 5:585-95.

6. Geyer, J. A., S. T. Prigge, and N. C. Waters. 2005. Targeting malaria with specific CDK inhibitors. Biochim Biophys Acta 1754:160-70.

7. Lu, J. Z., P. J. Lee, N. C. Waters, and S. T. Prigge. Fatty Acid synthesis as a target for antimalarial drug discovery. 2005. Comb Chem High Throughput Screen. 8:15-26.

KEYWORDS: natural products; high-throughput screen; mass spectrometry; malaria; infectious disease

A07-T035 TITLE: <u>Multi-Analyte, Wearable Chemical Nanosensor for Warfighter Physiological Status Monitor (WPSM)</u>

TECHNOLOGY AREAS: Chemical/Bio Defense

OBJECTIVE: Develop and demonstrate a minimalist body-worn system that uses porous silicon sensor technology to detect and classify volatile organic compounds (VOC)(e.g., benzene, toluene, xylene) in air, water, and urine. This technology will improve the “chemical situational awareness” of military personnel in the field by permitting field-expedient assessment of possible volatile organic compound exposure. The sensing system should be no larger than a typical Personal Digital Assistant (PDA).

DESCRIPTION: The ability to detect, classify and quantify target volatile organic compound (VOC) analytes using a small, low-cost, body-worn sensor should provide a powerful means of ensuring the near- and longer-term physiological well-being of Warfighters. Physically-active dismounted Warriors, who can have high rates of pulmonary ventilation and high rates of water consumption, are particularly at risk of volatile organic compound inhalation or ingestion.

Advances in nanotechnology science offer opportunities to transition sensor technologies from the laboratory to military and commercial products. In particular, recent advances in silicon- based sensor technologies show promise in rapidly detecting, classifying and determining the concentration of members of families of VOC analytes, using a single, compact, sensor element. Such a minimalist sensing capability is sought here to enhance Warfighter Physiological Status Monitor (WPSM) system capabilities. Specifically, the envisioned sensor should be characterized by suitable sensitivity, accuracy, precision, reversibility, speed, durability, reliability, simplicity, low power-consumption, very low weight, small physical size, low cost, minimal logistical impact, and ease of use. Sensor performance should be largely insensitive to environmental effects such as heat, dust and relative humidity. Proposed solutions must be able to withstand harsh conditions encountered in training and operational environments, including vibration, shock, and all weather conditions from deserts and mountains to swampy areas.

Examples of target volatile organic compounds (VOCs) analytes include benzene, xylene, toluene, and acetone. Within the family of analytes for which the sensor is designed, detection limits should be appropriate for the hazard or utility represented by the individual analyte. Reported and actual concentration of the analyte should closely match, and the value reported should be consistent when the sensor is repeatedly exposed to a constant concentration of the analyte – that is, sensor precision and reliability are important.

Under typical operating conditions, analyte concentration will vary significantly over time. This imposes requirements for good dynamic range and reversibility. Reversibility will be demonstrated by showing that it is possible to quickly “clear” or “reset” a previously exposed sensor, in anticipation of a future exposure-event.

Harmful effects portended by a detection event may be avoided through responsive action. Hence the speed with which the sensor responds should be commensurate with the threat represented by the particular analyte. In some potential applications, this requires response times of very few seconds, or less, not minutes or hours. In addition, unusual logistical requirements are unacceptable. The sensor must operate reliably, with very minimal calibration requirements and, under favorable conditions, should exhibit a useful lifetime before replacement. Assuming other desired performance parameters are addressed, including affordability, a disposable sensor is of interest, where such disposability would reduce maintenance and logistics footprints. However, a need for frequent sensor replacement to maintain proper functionality is undesirable. Simplicity of use under field conditions is essential; calibration and use-requirements need to be minimized. In general, the ability to detect, classify and report the concentration of a variety of analytes in the presence of interfering compounds is sought, the types of which will vary between applications to which the sensor technology is applied. Hence, to the greatest possible degree, the sensor technology should exhibit good selectivity, providing the desired information regarding the triggering analyte without significant interference from other compounds.

Minimizing the cost of the sensor and its interface technology is of strong interest. All monitor and control functions imposed by the sensor must be addressed through a simple, digital, communication interface, such as RS-232. The sensor system should have a minimal electromagnetic signature interference and be compatible for use in close proximity (within 0.5") to sensitive radio equipment. To facilitate use in network applications, sensors must provide information in digital format (e.g., unique identification number, time of detection event, analyte class and concentration, sensor status) in response to a external query. In addition, provisions for digital monitor-and-control of the sensor itself, to maintain proper operation of the sensor, may be required. Sensor may be used in stand-alone applications or as part of larger systems. So, not only is scalability to larger systems required, but uses will involve post-processing, transmission, storage and retrieval of sensor data by interested parties, for analysis, display and study.

PHASE I: Define the technological and product-migration paths from a threshold "trigger-sensor" to an advanced sensor that provides multi-analyte detection and exposure-characterization capabilities. Provide a proof-of-concept demonstration showing the viability of the chosen technical approach. The demonstration shall include the method for sampling and detection of one or more target volatile organic compound analytes under laboratory conditions. Sensitivity and specificity must be comparable to conventional methods. More specifically, C4-C20 alkanes and monomethylated alkanes in breath are of particular interest from a physiological monitoring point of view in that changes in these compounds can reflect oxidative strain or pathophysiological conditions (Phillips et al., 2000). The ability to test for the presence of these compounds at the 10 parts per million level with 90%+ sensitivity and specificity is desirable; relatively slow response and recovery times (e.g., 1 to 3 min, ideally 30 sec; sensor recovery in <30 sec) are acceptable. Experimentation with human test volunteers will not be needed. Conduct analyses and bench studies to provide initial information relative to sensor performance, power requirements and general feasibility for field use.

PHASE II: Develop a prototype sensor and demonstrate selectivity, insensitivity to common interferents, and stability towards zero point drift for the chosen technical approach relative to industry standards. The demonstration shall include the detection and discrimination of two or more target volatile organic compound analytes under field conditions of 25-75% relative humidity. Experimentation with human test volunteers will not be needed. Demonstrate the ability to operate the sensors in a wireless network. Develop and deliver at least five advanced prototypes. Provide a technical path to develop an advance sensor capable of multi-analyte detection in complex sample matrices.

PHASE III: The offeror should aggressively pursue a variety of other DoD, non-DoD governmental and private-sector applications. Networked application of this sensor technology would be useful for risk management in both static and mobile applications across a range of operational, first-responder, industrial and commercial environments in which there is the possibility of exposure to harmful volatile organic compounds.

REFERENCES:
1. Hoyt, RW and Friedl KE. Current status of field applications of physiological monitoring for the dismounted soldier. In: Metabolic Monitoring Technologies for Military Field Applications. M. Poos (Ed.). National Academy of Sciences, National Academy Press, 2004, pp. 247-257 (http://darwin.nap.edu/books/0309091594/html)

2. Monitoring at Chemical Agent Disposal Facilities (2005). The National Academies Press, Washington, DC, 2005 (http://www.nap.edu/catalog/11431.html#toc)

3. Pacholski, C.; Sartor, M.; Sailor, M. J.; Cunin, F.; Miskelly, G. M., Biosensing using porous silicon double-layer interferometers: reflective interferometric Fourier transform spectroscopy. J. Am. Chem. Soc. 127 (33): 11636-11645, 2005.

4. Phillips M, Cataneo RN, Greenberg J, Gunawardena R, Naidu A, Rahbari-Oskoui F.
Effect of age on the breath methylated alkane contour, a display of apparent new markers of oxidative stress. J Lab Clin Med. 2000 Sep;136(3):243-9.

5. Sailor, M. J.; Link, J. R., Smart Dust: Nanostructured devices in a grain of sand. Chem. Commun. 11:1375-1383, 2005.

6. Review of the Army's Technical Guides on Assessing and Managing Chemical Hazards to Deployed Personnel (2004) Board on Environmental Studies and Toxicology (BEST) The National Academies Press, Washington, DC, 2004 http://darwin.nap.edu/books/0309092213/html

7. TB MED 577 Technical Bulletin. Sanitary Control and Surveillance of Field Water Supplies. Technical Bulletin Medical 577. Headquarters Department of the Army. Washington, DC, 15 December 2005. http://chppm-www.apgea.army.mil/dehe/pgm31/TBs/TBMed577-15Dec2005.pdf

KEYWORDS: Ambulatory monitoring, wearable sensor, nanotechnology, industrial chemicals, alkanes, physiological status

A07-T036 TITLE: Innovative Lightweight Energy and Water Efficient Treatment System for Fluid Medical Waste in an Austere Deployed Environment

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: We are seeking an innovative method or system which will render liquid and other fluid medical (biohazard) waste products sterile and otherwise inert to the environment in austere, deployed locations. Currently autoclaving and/or chemical treatment (1:10 bleach solution) or open pit burning methods are used to support our Combat Support Hospitals (CSH), Forward Surgical Teams (FST), dental units, and other deployed medical units and treatment facilities.

Management of biological/medical waste in the deployed environment was identified as a key area of need for investigation and improvement by the participants at the TATRC sponsored Medical Logistics Integrated Research Team (IRT) conference conducted in May of 2005.

DESCRIPTION: The method now most frequently used in environments where infrastructure is limited, primitive, or does not exist, is often open-pit burning with a fuel accelerant source. Autoclaving may be available on a very limited basis and not sufficient to meet the overall requirements. Open pit burning is probably the least desirable way in which to dispose of liquid/fluid medical and biological waste products. Presently there is no field deployable system available that can inactivate/sterilize these waste products that is sensitive to the local population and friendly to the environment..

We are seeking a treatment method that is compact, lightweight, efficient in the use of power or fuel and requires minimal water consumption. The method should significantly reduce the volume of the treated fluid waste and the resultant effluent should ideally consist of steam and inert solids or slurry which can be safely vented and/or left in the environment.

PHASE I: Phase I will develop a methodology and design concept for a system that will render fluid medical/biological waste harmless to the environment. Since no such system exists today the solution will be both innovative and novel. Perhaps a process/system can be developed which will vaporize and/or melt the fluidized waste emitting steam and a small volume of slurry or inert solid waste as the byproducts. The desired system will be compact and require a minimum of energy to operate. The system should be easy to move, set-up, operate and maintain by soldiers in an austere environment. Water demands of this system should be minimal. Implicit in the design concept is a testing plan and metrics to assure that the system is capable of destruction of pathogens and the rendering of any effluent safe to the environment. This Phase I effort will span six months and will encompass no more that $100K of effort.

PHASE II: Phase II will result in the delivery of a functional prototype system. This prototype will, as close as possible, meet the requirements stated above for the Phase I design concept. The expectation is that at this point the prototype will be ready for commercialization and production in a potential Third Phase. This effort will encompass no more than two years and $750K worth of effort.

PHASE III: Significant dual use applications exist for this technology. Dual use applications include utilization at both civil and military medical, dental, veterinary and mortuary facilities. Additionally within the military such a system could be used in a number of areas beyond those enumerated above. Aboard Navy ships medical/biological wastes could be treated before discharge overboard. In remote or small medical facilities such a system might be used as the primary means of destruction of bio waste. also in remote locations or at smaller facilities such a system might be adapted to treat sewage or other septic waste. Civilian uses of the technology should parallel those of the military. The system could be of value in small or remote medical facilities, in small clinics or practices. The application might be used in hospital and other facilities to pre-treat certain medical/biological wastes before they are discharge into municipal sanitary sewage systems. A large "portable" version of such a system might be constructed that could be used in disaster situations to temporarily replace or supplement waste treatment systems damaged or destroyed by the event.

REFERENCES:
1. Dr. Jeremy Thompson and Dr. Honor Anthony, Moderators, "The Health Effects of Waste Incinerators", 4th Report of the British Society for Ecological Medicine, December, 2005

2. Policy Paper, World Health Organization, Safe health-care waste management, August 2004

3. Ira F. Salkin, Ph.D., "Review of Health Impacts from Microbiological Hazards in Health-Care Wastes", World Health Organization, 2004

4. "Canadian Company Receives Approval in the United States for a New Bio-Hazardous Waste Treatment Technology", Press Release, Ozonator Industries, July 27, 2006

5. "Device Could Do 'Battle' With Hospital Infections", ScienceDaily, August 5, 2006

6. "UB Device "sterilizes" contaminated air", University at Buffalo Reporter, March 4, 2004

KEYWORDS: waste treatment, medical waste, biological waste, biohazard

A07-T037 TITLE: Retinal Oximeter for Scientific and Clinical Applications

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Design, develop, and fabricate a retinal oximeter. This device should provide a totally non-invasive measurement of the blood oxygen content of the retinal vasculature. The instrument, in all probability, will be based on optical principles, measuring the relative spectral characteristics of lights reflected from the blood in specific retinal vessels (Delori 1988). The instrument should permit multiple or repeated measurements to be made using amounts of radiant energy well below that which has the potential of causing any retinal damage. The device should enable retinal oxygen measurements be made in individuals simultaneously with the performance of visually guided behaviors by the individuals. Therefore, the light used for making the measurements should have minimal visual impact. To achieve this minimal impact on vision, it may be necessary for the oximetry measurements to be obtained from the optic disk or possibly from defined peripheral areas of the retina that contribute minimally to the performance of visual tasks.

DESCRIPTION: Although there are several research groups currently working on such optically-based retinal oximeters (see references), none of these efforts are developing instruments that would have an important impact specifically on military applications. There are two particular issues. First, the current direction of most of these efforts is to develop a clinical tool for the examination of retinal vasculature in a wide range of ocular diseases. The instrument we are seeking to develop is not designed to address these clinical issues. What we are seeking is a tool that will provide the best information about the blood oxygen in the retina because that information will provide the best information about the blood oxygen of the cerebrum. Other measures of cerebral blood oxygen are either cumbersome or indirect, passing through substantial amounts of tissue; skin, muscle, bone. (Madsen & Secher, 1999, McKinley et al, 2005)) Such measures provide a gross or mass averaged index of cerebral blood oxygen. While retinal blood oxygen is not identical to that of the cerebrum, it promises to be a far more precise index than any current approaches. After all, under acceleration, vision loss due to anoxia is well known to be a sensitive leading indicator of loss of consciousness

The second important issue about the development of retinal oximeters for clinical purposes is that they are designed to provide a very precise map of the vasculature across the retina. To accomplish such precise maps they are very intrusive, essentially eliminating any useful vision from the eye while the oximetery measurements are being made. Furthermore, since the measurements expose the eye to substantial amounts of light, not only is the eye's sensitivity reduced by the light, but repeated exposures may even be hazardous. These devices, even if successfully developed for routine use in the clinic, are not useful for operational military purposes.

The important point for such military applications is that eye should not be incapacitated in any way while the measurements are being made. This is conceptually possible if the measurements are confined to the optic disc, an important area of the retina that is essentially blind since it has no photoreceptors although it does have vasculature. Since the oximeter almost certainly will need to make the measurements with light that is visible, by confining the light to the optic disk, the measurements can be made with little if any impact on the vision of the individual.

The outstanding issue then is to be able to aim the visible light onto the disk so that the measurements can made there. Such aiming can be accomplished with extra-spectral or infrared light that is invisible.

The realization of such a system will enable the monitoring of blood oxygen at the retina and thereby at the brain in an awake, conscious, and visually functioning individual. This capability will enable the simultaneous measurements of retinal (cerebral) oxygen and human visual cognitive performance in the behaving individual. This retinal oximeter will find its initial uses as a laboratory tool for investigating the effects of hypoxia on the performance of military personnel in operationally realistic laboratory scenarios.

The realization of this capability will open up the possibility of measuring retinal (cerebral) oxygen in warfighters in theatre. This would be a breakthrough technology that would have wide ranging impact for future capabilities and warfighter protection.

PHASE I: Conduct research to provide a proof-of-concept demonstration of a non-invasive, real-time optic disk retinal oximeter. This oximeter should be capable of making non-invasive, repeated oximetry readings confined to the vasculature of the optic disk of a cooperative awake human volunteer. The concept will be original or represent significant extensions, applications or improvements over published approaches.

Design and performance considerations for a proof-of-concept demonstration will include:

1. repeated retinal oximetry measurements to be safely made at the optic disk of the seeing eye of a behaving, cooperative, human observer engaged in visually guided behavior;
2. measurements made in an eye that is actively viewing the world;
3. a system that automatically tracks the optic disk so that the measurements can be confined to the optic disk and/or other defined retinal areas under operational conditions on such military platforms as aircraft and some land and sea vehicles;
4. the identification of key resources and capabilities necessary for realizing a prototype retinal oximeter for Phase II breadboarding, testing, and evaluation.

PHASE II: Expand upon the Phase 1 proof of concept functionalities to develop and integrate a prototype hardware realization of a non-invasive, real-time, retinal optic disc oximeter device.

Develop and test the device:

- that makes repeated (e.g. 2 Hz recordings for intermittent 2 minute periods) oximetry measurements in a human eye,
- as the device dynamically tracks such retinal landmarks as the optic disk and targets them for measurement,
- in the human eye as it views the world with a see-through optical system.

Demonstrate a road map for miniaturizing the device into a head-mounted system that has the potential for integration with current and projected future display technologies.

PHASE III: Evaluate and test the functionality of the integrated single device. This T&E will include the USAARL and collaborators in human performance studies to assess the precision, accuracy, and ease of use of the device. The retinal oximeter that the present SBIR will produce has many important potential military and civilian applications. Of course, the retinal oximeter will measure blood oxygen at the optic disk; but of equal important is the fact that blood oxygen measured at the optic disk is directly related to cerebral blood oxygen. This is particularly important for this SBIR since retinal oximetry may provide the most precise and accurate physiological index of cerebral blood oxygen that can be obtained with non-invasive, portable techniques.
Research: The retinal oximeter will be a research tool for studies designed to understand and anticipate the effects of altitude and its resultant hypoxia on the cognitive and performance capabilities of military and civilian aviators and aircrew personnel.

Training: The retinal oximeter may be integrated with altitude training, which itself is now being integrated in aviation simulation systems for aviators, both military and civilian (Artino et al, 2006, Sausen et al, 2005). That is, aircraft training simulators are being retrofit with the capability of simulating hypoxic conditions experienced at altitude.

Operational performance: The retinal oximeter will increase the safety and effectiveness of aviators. A precise robust reliable measure of cerebral blood oxygen, such as the retinal oximetery promises to provide, could control an oxygen delivery system for aircrew, both military and civilian. Such a system would monitor the retinal (cerebral) blood oxygen and increase oxygen flow as needed by the physiological demands of aircrew personnel as they perform their tasks at altitude.

Clinical and medical uses: The application of this device in a clinical setting would provide valuable information for the treatment of a host of retinal diseases. Hypoxic retina stimulates neovasular changes that destroy the vision of diabetics, premature infants and those with artery and venous occlusive disease, to name a few. This devise could determine the area of the retina that is hypoxic and allow for treatment that is focused and is provided prior to vision loss. Although the focus of the research community has been the development of a clinic tool, no such clinical tool is yet commercially available.

REFERENCES:
There is a rich literature on the development of retinal oximetry. The references listed below are only a small sample of recent reports in this developing and interesting field. Several of these provide optical analysis, and the report by Narasimha-Iylr and colleagues is a recent application of computer based image analysis techniques for the automated analysis of images of retinal vasculature. These types of techniques will almost certainly be key to solving some of the challenges posed by the application described in the present SBIR.

1. Artino AR Jr, Folga RV, & Swan BD. 2006. Mask-on hypoxia training for tactical jet aviators: evaluation of an alternate instructional paradigm. Aviation Space and Environmental Medicine; 77:857-63.

2. Beach JM., Schwenzer, JK., Srinivax, S., Kim, D., & Tiedeman, JS.: 1999. Oximetry of retinal vessels by dual-wavelength imaging: Calibration and influence of pitmentation. Journal of Applied Physiology. 86: 748-758.

3. Delori FC. Noninvasive technique for oximetry of blood in retinal vessels. 1988: Applied optics 27:1113-1125

4. Denninghoff, KR., Chipman, RA., Hillman LW: 2006. Oxyhemoglobin saturation measurements by green spectral shift. Optics Letters 31:924-926.

5. Denninghoff, KR., Smith, MH. 2000 Optical model of the blood in large retinal vessels. Journal of biomedical optics: 5 371-374.

6. Denninghoff, KR., Smith, MH., Lompado, A., & Hillman, LW. 2003. Retinal venous oxygen saturation and cardiac output during controlled hemorrhage and resuscitation. Journal of Applied Physiology, 94: 891-896.

7. Harris, A., Dinn, R.B., Kagemann, L, & Rechtman, E: 2003. A review of methods for human retinal oximetry. Ophthalmic surgery, lasers & imaging. 34: 152-164.

8. Masden, PL., & Secher, NH: 1999. Near-infrared oximetery of the brain. Progress in Neurobiology. 58:541-560.

9. McKinley RA, Tripp LD Jr, Bolia SD, Roark MR: 2005. Computer modeling of acceleration effects on cerebral oxygen saturation. Aviation, Space and Environmental Medicine; 76:733-738.

10. Narasimha-Iyer, H. Beach, JM., Khoobehi, B., Ning, J., Kawano, H & Roysam, B.: 2005. Algorithms for automated oximetry along the retinal vascular tree form dual wavelength fundus images. Journal of Biomedical Optics. 10: 054013-1 to 054013-15.

11. Nelsom, D.A., Krupsky, S., Pollack, A., Aloni, E., Melkin, M, Vanzetta, I., Rosner, M., Grinvald, A.: 2005. Special report: Noninvasive muli-parameter functional optical imaging of the eye. Ophthalmic surgery, lasers & imaging 36: 57-66.

12. Sausen KP, Bower EA, Stiney ME, Feigl C, Wartman R, & Clark JB. 2003. A closed-loop reduced oxygen breathing device for inducing hypoxia in humans. Aerospace and Environmental Medicine. 74(11):1190-1197.

13. Smith, MH, Denninghoff, KR., Lompado, A. & Hillman LW. 2000. Effect of multiple light paths on retinal vessel oximetry. Applied Optics. 39: 1183-1193.

KEYWORDS: Retinal oximetery, cerebral oximetery, hypoxia, retinal vascular system, vision, military performance, aviation, air crew

A07-T038 TITLE: <u>Military Surgical Information System</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: To design, develop, build and demonstrate a multimedia data and event capture system for the military health care system (MHS). The military surgical information system should allow integration of military specific and traditional operating room data to: improve quality of care of the individual soldier, improve quality of care of soldiers, dependents and retirees within the MHS, and eventually enable provision of real time decision support to deployed military healthcare providers. For example, the integration of patient care data with the operating room environment can prevent the soldier from receiving medicine to which he is allergic. This surgical information system should be of operational military value (trauma/occupational health focused across echelons of care).

DESCRIPTION: This topic falls into the category of DoD Key Technology Areas, Information Systems Technology. The desired outcome of this STTR topic is to develop a software system to capture patient data and events of the surgical procedure accurately and in real time that could be synchronized, compressed and included in an electronic health record to be used across all echelons of care. As President Bush stated in his State of the Union Address on 20 January 2004 “By computerizing health records, we can avoid dangerous medical mistakes, reduce costs, and improve care.”1 On August 22 2006, President Bush signed an executive order intended to increase the

"transparency" of the nation's health care system. Of relevance to the topic are the following components of the executive order:
1) Increase transparency in quality. Federal agencies are directed to share with beneficiaries information on the quality of services provided by physicians, hospitals, and other health care providers. The standards for measuring quality are to be developed in collaboration with multi-stakeholder groups and alliances.
2) Encourage adoption of health information technology (IT) standards. Agencies will improve their health IT systems to facilitate the rapid exchange of health information.
3) Provide options that promote quality and efficiency in health care. The executive order directs federal agencies to develop and identify approaches that support facilities and providers identified as providing high-quality and efficient care.2
In addition, Army medical centers have already engaged in a system of videoteleconferencing for the review of cases at deployed treatment facilities. The proposed solution would add to the capabilities of this system, allowing cases to be reviewed in real time by geographically isolated surgical specialists.

The multimedia data and event capture system would allow for the surgeon to start and stop the audio and video data capture of the surgical procedure at any time. The surgeon would be able to verbally dictate the progress of the procedure as they perform it as opposed to relying on memory and dictating/typing the procedural events afterwards as is current practice.3 Real-time gathering of information is especially important in combat support hospitals where multiple surgical procedures might be performed on multiple patients in one casualty event. All physiologic and anesthesia data, nursing intervention documentation, images and scans along with pertinent patient history and lab values supporting operative decisions would be readily accessible to both the on-hand staff as well as an external consulting physician. The consultant would be able to view all data in a synchronized manner along with current audio and video of the procedure. This system would allow the consultant to playback the audio/visual segments and view physiologic trends in patient status leading up to the consult. From a distant location the consultant would then be able to advise or telementor the surgeon in real time. The military would be able to integrate this data collection system into the soldier’s electronic health record. This system would remain with the soldier to provide continuity of care throughout the military healthcare system. The integration of traditionally disparate data sources such as physiologic monitors, intravenous pumps/rapid volume infusers, material management systems (medications, blood products, disposables), and surgical data systems should enable real time decision support that guides the deployed provider in the care of the patient. Such a system should enable data analysis such that variances in patterns of injury and treatment can be quickly identified and acted upon to improve quality of care within and between echelons of care.

PHASE I: Phase I will result in an assessment of technologies required to meet stated performance objectives, proof of feasibility and design plans for developing a multimedia data and event capture system.

Through the STTR program academia and small businesses can work together to develop such a system which would benefit military and civilian health care via improved patient safety due to more accurate and accessible records of often complex surgical procedures. Initial studies indicate that it is feasible to mentor and consult to a remote audience with video transmission of the surgical field.4 This topic would take the research in this area to the next level of practical military integration and application. The Performance objectives for this topic are as follows:

1-This system will incorporate audio and video records of the surgical procedure, where the surgeon has the ability to start and stop recording at any time.

2-The system should include but is not limited to: physiologic and anesthesia data, video and audio capture of the surgical procedure, nursing intervention and documentation, pertinent history and physical assessment data, intraoperative images and scans, laboratory values and pathology results.

3-The multimedia data and event capture system should be synchronized and have the capability for rapid review of previous still images, videos, voice, physiologic, laboratory and pathology data to allow for review by the surgeon or for use in consultation/telementoring in real time.

4-The system must be able to meet HIPAA privacy rights and allow for secure access from remote locations.

5-Open source solutions are preferable, interoperability with existing healthcare information systems is required. The surgical information system should be an open source, modular and flexible platform that allows real-time integration, storage, and access to available information throughout echelons of care (patient identification, patient tracking (GPS), physiologic monitoring, diagnostic, and therapeutic data).

6- From an operational standpoint, environmental data (eg, temperature, altitude, etc) should be able to be included in this system.

7-The system should also facilitate military medical research by facilitating extensive data analysis across traditionally disparate domains.

8- This information system should facilitate the tracking of blood, medication, and equipment down to the unit measure (RFID or bar coding). This could improve safety by providing validation of instrument, implant and disposable counts to monitor intentional and identify unintentional instances of materials left within the patient.

9- Please note there should be no human use in Phase I. However, planning and preparation of protocols and documents for human use in Phase II may begin during Phase I.

PHASE II: Phase II will result in the development and demonstration of a functional prototype of the multimedia data and event capture system. The team will assess any requirements for FDA approval during phase II and begin this process as required.

PHASE III: In Phase III the contractor will refine and execute a commercialization plan for the multimedia data and event capture system for both government and civilian sectors. The contractor might have the option of working with the Medical Research and Material Command to transition a superior system to an appropriate DOD acquisition organization for military use. Uses in the military sector include insertion of the system theater and CONUS medical treatment facilities (surgical facilities) to enable total electronic record keeping and real-time teleconsultation. In the civilian sector a successful system will be able to be integrated into large, potentially geographically dispersed healthcare systems for similar use. This system could also be used by aid organizations in the provision of medical care after natural disasters or other humanitarian crises so that geographically isolated surgical teams could have access to world class surgical expertise.

REFERENCES:

1. The White House State of The Union. January 20, 2004
http://www.whitehouse.gov/news/releases/2004/01/20040120-7.html

2. Executive Order: Promoting Quality and Efficient Health Care in Federal Government Administered or Sponsored Health Care Programs accessed at: http://www.whitehouse.gov/news/releases/2006/08/20060822-2.html

3. Houkin K, Kuroda S, Abe H. Operative record using intraoperative digital data in neurosurgery. ACTA NEUROCHIRURGICA 142 (8): 913-919, 2000.

4. Rafiq A, Moore JA, Zhao XM, Doarn CR, Merrell RC. Digital video capture and synchronous consultation in open surgery. Annals of Surgery 239 (4): 567-573, April 2004.

KEYWORDS: operative record, surgical errors, telementoring, event capture

A07-T039 TITLE: Real-Time, In Vivo Imaging to Identify Tumor Margins

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop and validate a real-time, in vivo imaging technique that will accurately identify tumor margins during breast tumor resection surgery.

DESCRIPTION: There have been many recent advances in biomarker identification, tracers, contrast agents, and techniques such as nanoparticle targeting, scintimammography, magnetic resonance, near-infrared and hyperspectral imaging (1-6) that have been applied to cancer diagnosis and treatment. This topic solicitation is directed toward the modification of one or a combination of existing technologies to provide a real-time imaging system capable of detecting precise tumor margins during breast-conserving surgery.

The use of lumpectomy, or breast-conserving surgery, is increasingly being used to treat operable breast cancers in place of mastectomy. Breast-conserving surgery currently involves excision of the visible tumor, along with a sizable section of surrounding tissue. The tumor margins and surrounding tissue are flash frozen, and spot samples are immediately analyzed by a pathologist to determine if additional tissue must be removed during the same procedure. These immediate, "spot sampling" examinations are not as accurate as analyses of permanent sections, and can lead to false-negative diagnoses and local recurrences of the cancer. 14% of patients that receive a lumpectomy followed by radiation therapy, and 39% of patients receiving lumpectomy alone, will go on to develop local recurrences (7). Furthermore, such recurrences are strongly correlated with the subsequent development of metastatic disease (8).

PHASE I: The goal of this phase is to explore the feasibility of imaging tumor cells within a larger population of cells. It is expected that the system's resolution will at a minimum allow detection of small clusters of tumor cells (>1 mm). The proposal may involve the development or modification of a novel imaging agent or system that takes advantage of a unique characteristic or set of characteristics of breast tumor cells, such as biomarkers or metabolic properties, and/or the modification of a novel imaging device appropriate for use in the operating room. Strategies for agent synthesis, delivery and detection should be addressed as appropriate.

Use of human cells and tissues and/or animals requires approval by the appropriate US Army Medical Research and Materiel Command regulatory office. Phase I should include approval of appropriate regulatory documents necessary to execute Phase II.

PHASE II: Using results from Phase I, develop a prototype combining the breast cancer-specific imaging agent and imaging method, and demonstrate its use for detecting tumor tissue in an animal model system and/or preliminary clinical testing in human tissue samples. The offeror should aim for a specificity and reproducibility of at least 95%. An experimental plan including the appropriate positive and negative controls should be outlined clearly.

In 2003, breast cancer treatment accounted for more than $56M in direct care costs throughout the Military Health System. The offeror should demonstrate the benefits the research will extend to warfighters and their family members by decreasing deaths due to secondary breast cancer. The platform should decrease the need for secondary surgeries and recurrences of cancers (i.e. breast cancer) that directly affect military personnel. The offerer is encouraged to demonstrate the universality of the platform to show the range of use in military and civilian medical applications.

PHASE III: This phase would involve optimization and clinical testing of the system to demonstrate FDA marketability. Show the platform as a tool for state of the art care for military personnel and DoD beneficiaries. The commerciality potential of a Phase III project is expected to be high. An intraoperative imaging method that can confidently assist surgeons in determining clear tumor margins will have widespread application for the treatment and future mortality and morbidity of breast cancer patients in both military and civilian sectors. Having the ability to obtain real-time information and feedback in the operating room will allow surgeons to maximize the extent of tumor resection while sparing normal breast tissue. Additional benefits may include improving the diagnostic accuracy of intraoperative biopsies and reducing the cost and discomfort of surgical breast cancer treatments.

REFERENCES:
1. Haglund MM, Berger MS, Hochman DW. Enhanced optical imaging of human gliomas and tumor margins. Neurosurgery. 1996. 38:308-17.

2. Hogemann-Savellano D, Bos E, Blondet C, Sato F, Abe T, Josephson L, Weissleder R, Gaudet J, Sgroi D, Peters PJ, Basilion JP. The transferring receptor: a potential molecular imaging marker for human cancer. Neoplasia. 2003. 5:495-506.

3. Gao X, Cui Y, Levenson R, Chung LWK, Nie S. In vivo cancer targeting and imaging with semiconductor quantum dots. Nat Biotechnol. 2004. 22:969-76.

4. Duarte GM, dos Santos CC, Torresan RZ, Alvarenga M, Telles GH, Bianchessi ST, Caserta N, Segala SR, Lopes de Lima Mda C, de Camargo Etchebhere EC, Camargo EE. Radioguided surgery using intravenous 99mTc sestamibi associated with breast magnetic resonance imaging for guidance of breast cancer resection. Breast J. 2006. 12:202-7.

5. Uzgiris EE, Sood A, Bove K, Grimmond B, Lee D, Lomnes S. A multimodal contrast agent for preoperative MR imaging and intraoperative tumor margin delineation. Technol Cancer Res Treat. 2006. 5:301-10.

6. Martin ME, Wabuyele MB, Chen K, Kasili P, Panjehpour M, Phan M, Overholt B, Cunningham G, Wilson D, Denovo RC, Vo-Dinh T. Development of an advanced hyperspectral imaging (HIS) system with applications for cancer detection. Ann Biomed Eng. 2006. 34:1061-8.

KEYWORDS: breast cancer, tumor margins, lumpectomy, imaging

A07-T040 TITLE: Standoff Remote Triage Sensor Array for Robotic Casualty Extraction Systems

TECHNOLOGY AREAS: Biomedical

OBJECTIVE: Develop an array of stand-off Joint architecture for Unmanned Systems (JAUS) wireless physiological assessment and trauma sensors for implementation on combat casualty extraction robots being developed by the Army Medical Research and Materiel Command (USAMRMC) and the Tank Automotive Research Development and Engineering Center (TARDEC)under the Army-Marine Corps Ground Robotics Master Plan.

DESCRIPTION: This sensor array is intended to prevent further injuries during robotic extraction of combat casualties under fire or in otherwise hostile environments by enabling first responders to perform remote triage and standoff trauma assessment via ABCDE (Airway, Breathing, Circulation, Deficit, Exposure) and Glasgow Coma Score procedures. Significant research and development efforts are underway within the US Army Medical Research and Materiel Command (USAMRMC) and the Future Force Warrior Program to develop the Warrior Personal Status Monitor (WPSM) as a device for remote triage on US troops; however, many of the casualties treated by US forces during current and future asynchronous peacekeeping and counterinsurgency operations will not be American soldiers and will not be wearing a WPSM, even in the future. Therefore a remote triage and standoff casualty assessment system, which is not dependent upon the casualty wearing a monitor, is needed. Several emerging technologies are potential candidates for this research topic. These include ultra wide band radar motion detection for respiration, pulse, and/or tetany type muscle spasms associated with nerve agent exposure; intelligent and laser-based pulse oximeters; oxygen/carbon dioxide respiration sensor arrays; accoustic cardiac, blood pressure and respiration sensors; micro-electronic machine systems (MEMS) electrocardiogram sensors and near infrared (NIR)sensors for hydration status. Research challanges inherint in this topic include sensor array selection, development, and integration; miniturization; power; JAUS compliant command and control; and integration with and implementation on robots. Descriptions of Army Combat Casualty Care Extraction and Evacuation Unmanned Ground Systems (UGVs) and robots which are the integration targets for this prototype sensor array are contained in the Army Marine Corps Ground Robotics Master Plan published by the Robotics Joint Program Office, Restone Aresenal, Al. Descriptions will be provided on the DOD SITIS website for this SBIR topic.

PHASE I: Conceptualize and design a prototype array of stand-off wireless physiological assessment and trauma sensors for implementation via the Joint Archtitecture for Unmanned Systems (JAUS) on combat casualty extraction robots currently being developed under the Army-Marine Corps Ground Robotics Master Plan. Develop a research plan for Phase II.

PHASE II: Develop, integrate and demonstrate a prototype array of stand-off wireless physiological assessment and trauma sensors for implementation via the Joint Archtitecture for Unmanned Systems (JAUS) on combat casualty extraction robots currently being developed under the Army-Marine Corps Ground Robotics Master Plan. Develop a commercialization plan for Phase III.

PHASE III: Assist the Army in transitioning and implementing the prototype array of stand-off wireless physiological assessment and trauma sensors via the Joint Architecture for Unmanned Systems (JAUS) on prototype combat casualty extraction robots described in the Army-Marine Corps Ground Robotics Master Plan. Transition the integrated system to a program of records such as the Army PM Force Protection Family of Integrated Rapid Response Equipment (FIRRE) or the Army Future Combat Systems (FCS). Develop and market a commercial version of the sensor array for use by civilian emergency first responders.

REFERENCES:
1. Brower, J.M. “Vitality Signs”. Military Medical Technology. Aug 2004. 8(5):36-38.

2. Evans, C. P. and R. J. Watts. The TARDEC Robotics Skunk Works Project: A Modular Approach to Unmanned Ground Systems. Proceedings of the SAE 2006 Commercial Vehicle Engineering Congress and Exhibition. In press.

3. http://www.atmeda.org/news/2004_presentations/t3d1.gilbert.ppt; and
http://www.tatrc.org/website_robotics/pdf_files/USAMRMC_TATRC_Medical_Robotics.pdf

4. Reifman, J., G. R. Gilbert, M. Parker and D. Lam. 2004. “Challenges of Electronic Medical Surveillance System.” Proceedings of RTO HFM Symposium on NATO Medical Surveillance and Response: Research and Technology Opportunity and Options. Budapest, Hungary, 19-21 April 2004.

5. http://www.tatrc.org/website_robotics/index.html

6. http://www.natick.army.mil/about/pao/2001/01-58.htm

7. http://www.armymedicine.army.mil/news/mercury/05-06/sensors.cfm

8. http://www.military-medical-technology.com/article.cfm?DocID=560

9. http://www.radiancetech.com/products/triage_sensor.htm

KEYWORDS: robot, sensors, remote triage, combat casualty care, casualty extraction