APPLICATION OF SYNTHETIC BIOLOGICAL TECHNIQUES FOR ENERGETIC MATERIALS

1. Objective of Proposed Work

The objective of this Statement of Need (SON) is to develop innovative synthetic biological approaches to produce critical U.S. military energetic ingredients and their precursors using renewable resources and bioprocesses that reduce hazardous waste streams, energy usage, and waste disposal costs encountered with the existing conventional organic manufacturing processes. Both fundamental research to develop approaches applicable to these classes of compounds as well as applied research targeting a specific energetic compound or precursor is of interest.

Proposals will be considered for targeted applications, where the focus should be on a specific end-point in which synthetic biology is used as an alternative method of producing a known energetic chemical or precursor such as:

- biosynthesis of guanidine and nitroguanidine,
- biocellulose for nitrocellulose production, and
- nitrogen heterocyclic structures such as dianinofurazan, precursor to explosives such as:
  - 4,4'-diamino-3,3'-azoxyfurazan (DAAF), and
  - oxadiazole precursor to many new explosives, for example 3,4-dinitrofurazanfuroxan (DNTF).

Proposals will also be considered for more broad-based research to develop the fundamentals of synthetic biology as related to energetic materials with no specific targeted compounds. This could include aromatic nitration, nitramine formation, oxidation of amines to nitro groups, and oxidation of amines or ring closure reactions to yield N-oxides.

It is recognized that the current state of the technology may also require the use of chemical synthesis techniques to achieve total synthesis of the selected energetic material; however, biosynthetic techniques that circumvent the use of heavy metal catalysts and traditional organic solvents that have current or may have future environmental regulatory restrictions are preferred. It is anticipated that the development of synthetic biological tools, especially nitrination tools, will reduce the need to employ these “bridging” chemical synthesis steps and lead to the adoption of completely biosynthetic methods for the production of energetic ingredients. Such new biosynthetic strategies must result in reduced and/or less toxic waste streams. Genomic studies and gene expression proposals that lead to relevant and new biocatalysts will also be considered under this SON. Proposals that emphasize traditional chemical synthesis, even when these are
claimed to be “non-polluting,” will not be considered. Choice of appropriate targeted compounds or broad classes of compounds for this investigation should be based upon their suitability for widespread use in the DoD and their potential for biosynthesis.

2. Expected Benefits of Proposed Work

The supply of military critical energetic materials relies heavily upon petroleum-based starting materials and upon foreign sources that manufacture materials not available in the U.S. due to environmental regulations. The development of environmentally benign bioprocesses for the production of energetic compounds and their precursors from renewable resources has the potential both to reduce the reliance upon foreign sources and promote manufacturing capability within the U.S. Improved environmentally responsible syntheses of energetic materials or biochemical nitration techniques will substantially reduce hazardous wastes and undesirable by-products through the elimination of high volatile organic compound (VOC) solvents, heavy metal catalysts, and toxic chemicals used by the current classical, highly polluting and inefficient chemical routes. In addition, product yields are expected to be higher than those of the conventional processes due to the high efficiency and selectivity of conversions. Innovative biochemical synthesis routes are important from an environmental perspective since they are typically run under mild conditions, avoid the use of heavy metal catalysts, virtually eliminate undesirable isomers and by-products, produce little or no hazardous waste, result in energy savings, and frequently provide high product yields.

3. Background

The term ‘synthetic biology’ describes research that combines biology with the principles of engineering to design and build standardized, interchangeable biological DNA building-blocks. These have specific functions and can be joined to create engineered biological parts, systems, and, potentially, organisms. It may also involve modifying naturally occurring genomes to make new systems or by using them in new contexts. Established DNA research methods involve using genetic material from existing organisms whereas under synthetic biology, DNA sequences can now be designed using computers and chemically synthesized in the laboratory. Synthetic biology is the next step in synthetic chemistry in that it extends the ability to create novel molecules and molecular systems and to develop novel materials.

In analogy to electrical engineering, synthetic biology envisions a hierarchy for biology in which genes and proteins (individual parts) are assembled in increasingly complex devices and networks, in the same way in which individual transistors are assembled into integrated electronic circuit. Multiple devices (genes, prompters, enzymes, etc.) can be hooked together thereby creating “systems” or “modules” capable of complex behaviors. Achievement of this capability can lead to rapid developments in many areas including development of new, inexpensive drugs and vaccines, biosensors, bioremediation tools to process contaminants, and new biological production techniques for novel materials and chemicals, including biofuels and energetic materials.

A new approach must be developed for the synthesis and manufacture of energetic materials and their precursors since:
• Energy- and solvent-intensive legacy routes from petroleum feedstocks are driving material costs and environmental consequences of their production to unacceptable levels; and
• Critical feedstocks and associated chemical technologies are often of foreign origin, and therefore potentially unreliable and weaken national security.

Fortunately, advances in biochemistry, molecular genetics and genomics, and parallel developments in industrial-scale bioprocessing, are beginning to offer realistic and cost-effective alternatives to classical chemistry and chemical engineering for the production of energetic materials.

While chemical steps may occasionally be used (with justification) to circumvent currently infeasible biochemical ones, the entire emphasis and strategy of proposed synthesis schemes must be to exploit biosynthetic routes.

4. Cost and Duration of Proposed Work
The cost and time to meet the requirements of this SON are at the discretion of the proposer. Two options are available:

Standard Proposals: These proposals describe a complete research effort. The proposer should incorporate the appropriate time, schedule, and cost requirements to accomplish the scope of work proposed. SERDP projects normally run from two to five years in length and vary considerably in cost consistent with the scope of the effort. It is expected that most proposals will fall into this category.

Limited Scope Proposals: Proposers with innovative approaches to the SON that entail high technical risk or have minimal supporting data may submit a Limited Scope Proposal for funding up to $150,000 and approximately one year in duration. Such proposals may be eligible for follow-on funding if they result in a successful initial project. The objective of these proposals should be to acquire the data necessary to demonstrate proof-of-concept or reduction of risk that will lead to development of a future Standard Proposal. Proposers should submit Limited Scope Proposals in accordance with the SERDP Core Solicitation instructions and deadlines.

5. Point of Contact
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For Core Proposal submission due dates, instructions, and addition solicitation information, visit the SERDP web site at www.serdp-estcp.org/Funding-Opportunities/SERDP-Solicitations.