

**BAA 07-35**

**Ultrapformance Nanophotonic Intrachip  
Communication (UNIC)**



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The Defense Advanced Research Projects Agency (DARPA) often selects its research efforts through the Broad Agency Announcement (BAA) process. The BAA will appear first on the FedBizOpps website, <http://www.fedbizopps.gov/> and Grants.gov website at <http://www.grants.gov/>. This BAA document constitutes the entire solicitation.

DARPA is soliciting innovative research and development (R&D) proposals in the area of Ultrapformance Nanophotonic Intrachip Communications (UNIC) with the goal of demonstrating low power, high bandwidth, low latency intrachip photonic communication networks designed to enable chip multiprocessors with hundreds or thousands of compute cores to realize extremely high computational efficiency (actual performance). The proposer will be expected to select aggressive chip multiprocessor “design drivers” in a future technology node (~ 20 nm), and to design for them credible, high connectivity photonic networks that are non-blocking and have low message latencies, narrow latency distributions, high communication bandwidth (to accommodate all expected traffic) and other characteristics that *minimize programming effort*. Detailed

analyses of network communication parameters and demonstration of system-level performance benefits for their chosen network designs are expected. The proposer will also present plans on how they will achieve the photonic device performance required for implementation of their photonic network designs. Proposers will also be expected to demonstrate *functional intrachip photonic communication links incorporating all critical photonic and electronic components/technologies working together on a chip* and demonstrate link performance that *validates* the photonic network designs and the expected system performance benefits.

Proposed UNIC R&D should investigate innovative approaches that enable revolutionary advances in science, devices, circuits, and computing systems. Specifically excluded is R&D that primarily results in incremental or evolutionary improvements to the existing state of practice.

## **1. Background and Description**

Impressive progress in nanofabrication technology has led to a high density of functional elements per unit area and volume in integrated electronic systems. Microprocessor chips currently have of the order of one billion transistors per square centimeter and may have hundreds of billion transistors per square centimeter within the next decade. Similarly, molecular memory density may exceed  $10^{12}$  elements per cubic centimeter. Facilitating communication between these ultrahigh density functional elements and the external world is becoming increasingly more difficult. This extraordinarily difficult communication challenge must be addressed if the full potential of systems with such ultrahigh integration density is to be realized. The vision of DARPA's UNIC (Ultraperformance Nanophotonic Intrachip Communication) Program is to address this communication challenge through the development of high bandwidth, low power nanophotonic communication at the chip level.

Photonic technologies have made enormous strides in recent years. High performance Silicon photonic devices have been demonstrated in a CMOS-compatible fabrication process, e.g. by DARPA's EPIC (Electronic and Photonic Integrated Circuits) Program, setting the stage for UNIC effort. Photonic technologies have come to dominate communications in wide area, metropolitan area and local area networks, and are making impressive inroads into rack-to-rack, board-to-board and chip-to-chip communications. Photonics brings high bandwidth, low latency, and low power options to communications and is the natural technology to address the communication challenges related to ultrahigh density functional elements on a chip.

The UNIC program will focus on addressing the communication challenges emerging for high performance microprocessor chips with billions of transistors per square centimeter. Processor chips with multiple cores have arrived, and the trend is expected to continue to hundreds or thousands of cores on a chip. Electrical communication between these cores, and from the multiprocessor chip to external memory and peripherals, is expected to have limited bandwidth due to power constraints. This will increase the imbalance between the computation performance (FLOPS) and the communication bandwidth (Bytes/s), leading to *actual performance* much lower than the *theoretical peak performance* of the multicore chip. The UNIC program challenges the

community to demonstrate that low power, high bandwidth, low latency intrachip photonic communication, with seamless interface to the external world, will allow the *actual performance* to track expected increase in the *theoretical peak performance* of the chip multiprocessors while minimizing programming efforts.

## **2. Technical Areas of Interest**

The UNIC program has two Technical Areas of Interest. **All proposals are required to address both technical areas of interest in a comprehensive manner.** A team approach is strongly encouraged.

### Area of Interest I: Photonic Network Architecture and Required Photonic Devices

The first Area of Interest focuses on the development of credible architectures for the intrachip photonic communication networks, demonstration of substantive system performance benefits resulting from these networks, identification of photonic devices and device performance requirements, and experimental demonstration of such device performance.

- A. Development of flexible and scalable architectures for intrachip photonic communication networks based on “design drivers” for a chip multiprocessor with hundreds/thousands of computation cores in the ~ 20 nm node. The intrachip photonic networks should provide photonic communication links between various electronic functional units on the chip multiprocessor and enable significantly enhanced microprocessor performance in terms of communication parameters (bandwidth, latency, throughput), power dissipation, and overall system performance for a wide range of applications of DoD (and other) interest. Architectures and performance should be scalable to the end of Moore’s Law. DARPA has a strong interest in high connectivity photonic networks that are non-blocking and have low message latencies with acceptable bounds, narrow latency distributions, large communication bandwidths (to accommodate all expected traffic) and other characteristics that *minimize programming effort*. The overall perspective should be the maximization of performance while minimizing required programming effort (by reducing the need for a programmer to understand the specific multiprocessor hardware structure). The photonic architecture should also provide seamless photonic communications to external memory and I/O. Provide the most aggressive designs in terms of total chip power consumption, performance, chip size, etc.
- B. Development of photonic devices such as modulators, filters, switches etc. necessary to realize the intrachip photonic architectures. The device challenges, in addition to high performance in terms of speed, spectral bandwidth, etc., include, but are not limited to, extremely low power dissipation, small footprint, low loss, and thermal stability/tunability. The photonic devices should allow aggressive scaling to low power and small size, and should be fully compatible with current CMOS electronic fabrication for integration with chip multiprocessors. Devices should be shown to be scalable for intrachip photonic communication networks to the end of Moore’s law.

- C. Analysis of the actual system-level performance benefits of the complete design normalized to total chip power consumption, chip size etc. Only those photonic architectures and designs that provide substantial system-level benefits compared to all-electronic solutions, while minimizing programming efforts, should be presented. Furthermore, approaches that are specific to a given problem are of low interest.

### Area of Interest II: Integration/Demonstrations

The objective of this Area of Interest is to establish the credibility of intrachip photonic communication and increase the likelihood that this technology would be accepted by the microprocessor community. DARPA is interested in aggressive experimental demonstrations that accomplish these objectives. Demonstration of *functional intrachip photonic communication links incorporating all critical photonic and electronic components/technologies working together* at a performance level that validates the design in Area of Interest I is expected.

## **3. Program Requirements**

### **3.1 Design Drivers**

The first step in preparing the technical proposal is to select an aggressive chip multiprocessor design driver, with hundreds or thousands of computational cores. The design driver is a chip multiprocessor “black box” with certain properties/characteristics that forms the basis for designing appropriate intrachip photonic communication networks. Architectural assumptions about core design, memory hierarchy, etc. for the design driver should be stated, and should be reasonable given technology projections for the ~20nm node, but the optimized design of the chip multiprocessor or the individual cores are *not* to be addressed in this program.

Both Design Driver A and B must be addressed in the proposal. Additional Design Drivers are optional.

Design Driver A: A chip-scale, fully integrated solution for tight SWaP (Size, Weight and Power) applications, including the maximum memory capacity which can be integrated on chip (monolithically, or through 3D integration). “Design Drive A” is assumed to have the following properties: Aggregate peak theoretical computation performance ~ 10 TFLOPS or greater (double precision), a single or multiple interconnected chips no larger than the maximum reticle size of ~ 600 mm<sup>2</sup> expected for the ~ 20 nm technology node and 30 GB of on-chip memory. The cores may individually have access to the photonic network, or multiple cores may be grouped into a “supercore”, whose size is small enough ( $\leq 2\text{-}3$  mm) to allow power-efficient internal electrical communication, and which serves as a single point of access to the photonic network. The total electrical power dissipation for design driver chip multiprocessor (including logic, memory and electrical communication within all supercores) is ~ 200 W.

Design Driver B: A board-level solution which accommodates a larger external memory to address bigger problems in embedded applications or which is appropriate as a node in a supercomputer application. Design driver B incorporates 500 GB of external memory (external to the chip multiprocessor) to design driver A and with or without the internal 30 GB memory. A photonic intrachip communication network for this design driver must include seamless photonic communication to this external memory. Connections to external memory can be using fibers or optical waveguides.

Additional Drivers: Offerors may also select *additional* design drivers (in addition to design drivers A and B) to illustrate the versatility and benefits of their approach.

Extreme care should be taken in the design to avoid “inverted memory” architectures.

### **3.2 Photonic Network Designs**

For the chosen design drivers, proposers must present credible designs for high-connectivity photonic communication networks that are non-blocking and have low message latencies, low distribution of latencies, sufficiently high bandwidth to satisfy all communication requirements, high throughput under high loads and other characteristics that minimize programming effort. In addition, the network designs must facilitate low power, seamless off-chip photonic communications. Network and memory bandwidths should be such that the ratio of Bytes/s) to FLOPS exceeds unity.

The proposers must also discuss physical implementation/layout of intrachip photonic communication networks for chip multiprocessors, integration with the chip multiprocessor, and signal paths between electronic and photonic systems. The proposed fabrication for the photonic network must be fully compatible with CMOS processing, either through monolithic integration or back-end-of-the-line integration/packaging. The physical layout of the interconnected processor/photonic network must be clearly specified.

### **3.3 Photonic Network Communication Analysis**

Proposers must also quantify latencies, distribution of latencies, communication bandwidth and throughput as a function of offered load for all network designs. Photonic networks must be aggressively optimized to minimize the on-chip photonic and electronic power required for operation with desired characteristics, and this total on-chip power must not exceed 50 W. This includes any electrical power required for converting data formats between electrical and optical formats, for controlling the photonic network, and any on-chip power required for off-chip communication to the external memory. Proposers are encouraged to consider different network designs and compare their performance based on parameters discussed above (see also Section 3.4).

### **3.4 Photonic Communication Network Benefits**

The proposers must provide an in-depth analysis of system-level benefits of their photonic network designs compared to an electrical communication network with the same communication power and size limitations. The analysis of system-level benefits should be conducted from several perspectives, including but not limited to: (A) HPCChallenge benchmarks such as HPL, STREAM, FFT, and RandomAccess, (B) DoD-relevant applications such as Synthetic Aperture Radar Processing or Persistent Surveillance, or supercomputer applications, and (C) simplification or ease of programming. Only designs (for design drivers A, B and others) leading to substantial system-level benefits should be proposed. A comparison to future all-electrical network solutions, demonstrating significant gains achieved by incorporating photonic technologies should be presented.

### **3.5 Device Requirements**

The proposers must quantify the performance requirements for all photonic and electronic devices necessary to implement the photonic network designs proposed by them. They must provide a detailed discussion of how the total network power dissipation on chip meets the design criteria in Section 3.2. They must show that there is a credible pathway to reaching these performance milestones, and present a timeline for reaching these quantitative milestones. The devices for meeting individual performance goals and in the link demonstrations must be fabricated in fully CMOS-compatible process.

### **3.6 Validation Demonstrations**

The proposers must demonstrate *functional intrachip photonic communication links incorporating all critical photonic and electronic components/technologies working together* and demonstrate performance for the links that validate the designs in Section 3.2. Quantitative performance milestones for these demonstrations and their timeline must be clearly presented. Proposers must also present a concise discussion of the test measurement set-up and the measurements procedures for the link demonstrations.

## **4. Deliverables**

The primary deliverables for the UNIC program are the final experimental demonstration of the Intrachip photonic communication link validating the designs in their proposals, and a final technical report, which includes the transition plan. Intermediate reports, at quarterly intervals and will also be required.

## **5. Program Scope**

The UNIC program will consist of two phases: the first phase will focus primarily on the development, fabrication and demonstration of photonic devices with aggressive

milestones on the path to meeting the requirements of the network design. The first phase will also focus on refining and optimizing the most aggressive intrachip photonic network designs for the best system-level performance, and on preparing for the intrachip photonic communication link demonstrations in the second phase. The second phase will focus primarily on intrachip photonic communication link demonstrations that validate the designs of the photonic networks and establish the credibility of the technology in the microprocessor community. Aggressive photonic device development will continue in Phase II with the goal of demonstrating device performance essential for realizing the Intrachip photonic communication networks that lead to the system-level benefits expected from performers' analyses. Proposers must define a realistic schedule and budget to meet the milestone and deliverable schedule. Program plans should include interim milestones every six months. Multiple awards are anticipated. Collaborative efforts/teaming including different expertise are strongly encouraged. These include expertise in areas such as, but not limited to: Communication network design, microprocessor performance and system analysis, nanophotonic and electronic device design, fabrication, and packaging, integration and testing of photonic/electronic devices forming communication links on a chip. Cost sharing is not required and is not an evaluation criterion, but is encouraged where there is a reasonable probability of a potential commercial application related to the proposed research and development effort. Interested organizations are requested to contact the BAA e-mail address ([BAA07-35@darpa.mil](mailto:BAA07-35@darpa.mil)) before 8 May 2007 expressing intent to submit. This will allow the appropriate government personnel to be assembled to evaluate all proposals.

## **6. Proposal Management**

### **6.1 BAA Correspondence**

DARPA will use electronic mail for all technical and administrative correspondence regarding this BAA. Administrative, technical or contractual questions should be sent via e-mail to [BAA07-35@darpa.mil](mailto:BAA07-35@darpa.mil). If e-mail is not available; please fax questions to (703) 696-2206 (Attention: Dr. Jagdeep Shah). All requests must include the name, address, and phone number of a point of contact. Technical and contractual questions should include the originator's full name, email, and postal address in the text.

### **6.2 Frequently Asked Questions**

All questions and answers of relevance to the community will be posted to a "Frequently Asked Questions (FAQ)" accessible at:  
<http://www.darpa.mil/mto/solicitations/>

### **6.3 Period of Solicitation**

This BAA will remain open from 24 April 2007 through 24 April 2008. For consideration during the initial round of selections, proposers are required to submit

proposals by 3:00 PM Eastern Standard Time on 7 June 2007. However, proposals received after this deadline may be evaluated up to 1 year from date of posting.

#### **6.4 Submission Guidelines**

Proposals should be submitted electronically using the following submission method:

DARPA/MTO will employ an electronic upload process, the Technical Financial Information Management System (T-FIMS) Proposal Submission System, for proposal submissions to this BAA. The T-FIMS Proposal Submission System can support the following file formats: Portable Document Format (PDF), Word Document (doc), Plain Text (txt), Comma-separated Values (CSV), PowerPoint Presentation (ppt), Excel Worksheet (xls), and Excel Workspace (xlw). Proposal submissions made through the T-FIMS Proposal Submission System must be no larger than 50 megabytes per file. All material submitted electronically must be UNCLASSIFIED. Please DO NOT attempt to submit a CLASSIFIED material proposal through an electronic upload process as this is PROHIBITED. Offerors that intend to include classified, or potentially classified, information or data as part of their proposals should follow procedures discussed in Section 13 below.

Electronic proposals should be in Microsoft Word format or PDF and submitted via a web site interface: Web Site: <https://www.tfims.darpa.mil/baa>.

Proposals may not be submitted by fax or e-mail; any sent in this manner will be disregarded.

*Organizations submitting their proposals through Grants.gov do not need to submit to the T-FIMS system.*

Historically Black Colleges and Universities (HBCU), Minority Institutions (MI), Small Businesses (SB), and Small Disadvantaged Businesses (SDB) are encouraged to submit proposals and join others in submitting proposals; however, no portion of this BAA will be set aside for these organizations' participation.

#### **6.5 Proposal Registration**

Organizations planning to submit proposals must register at: <http://www.tfims.darpa.mil/baa>. Only the lead or prime organization should register. One registration per proposal should be submitted. By registering, the Proposer has made no commitment to submit. The deadline for T-FIMS registration is 24 May 2007. *Please note: if the registration date is missed, the offeror may not be able to upload their proposal by the published proposal submission due date.*

## **7. Proposal Handling**

Restrictive notices notwithstanding, proposals may be handled, for administrative purposes only, by a support contractor. This support contractor is prohibited from competition in DARPA technical research and is bound by appropriate nondisclosure requirements.

## **8. Teaming Arrangements**

**All proposals are required to address both technical areas of interest in a comprehensive manner.**

Integrated teams capable of addressing different technological and scientific aspects of the UNIC program will be highly valued. Teams composed of partners from academia, industry, and national laboratories are encouraged. A website (<http://www.davincinetbook.com/teams>) will be established to facilitate teaming between interested parties. Specific information content, communications, networking, and team formation are the sole responsibilities of the participants. Neither DARPA nor the Department of Defense (DoD) endorses the destination website or the information and organizations contained therein, nor does DARPA or the DoD exercise any responsibility at the destination. This website is provided consistent with the stated purpose of this BAA.

## **9. Evaluation Criteria/Evaluation and Funding Processes**

Proposals will not be evaluated against each other because they are not submitted in accordance with a common work statement. DARPA's intent is to review proposals as soon as possible after they arrive; however, proposals may be reviewed periodically for administrative reasons.

For evaluation purposes, a proposal is the two-volume document described in Section 10. Other supporting or background materials submitted with the proposal will be considered for the reviewer's convenience only and will not be considered part of the proposal.

Evaluation of proposals will be accomplished through a technical review using the following criteria, which are listed in descending order of relative importance: (1) overall scientific and technical merit, (2) potential contribution and relevance to the DARPA mission, (3) plans and capability to accomplish technology transition, (4) offeror's capabilities, related experience, and relevant past performance, (5) schedule realism, and (6) cost reasonableness and realism. Cost and price reasonableness will be made prior to award. The following are descriptions of the above listed criteria:

- (1) Overall Scientific and Technical Merit: The technical approach of the offeror should address every aspect of the effort. In particular, the following items will be considered and evaluated:
  - Revolutionary aspects of approach,
  - Scientific and technical merit of proposed approach to research,

- Soundness of proposed work, and
  - Probability of success.
- (2) Potential Contribution and Relevance to the DARPA Mission: The potential contributions of the proposed effort with relevance to the national technology base will be evaluated.
- (3) Plans and Capability to Accomplish Technology Transition: The offeror's plans and capability to transition the technology to the research, industrial, and operational military communities in such a way as to enhance U.S. defense. The extent to which Technical Data and Computer Software are proposed as being delivered with less than Unlimited Rights, as well as supporting background Patents, will be considered when evaluating technology transition (i.e., barriers to transition).
- (4) Offeror's Capabilities, Related Experience, and Relevant Past Performance: The capabilities of the offeror to perform the stated work and their relevant past performance will be examined, with an emphasis on past performance on DARPA contracts. In particular, DARPA will consider the qualifications of principal investigators and their performance on projects of similar technical goals and scale. DARPA will evaluate the range, depth, and mix of expertise of the offerors' key personnel to ensure that key personnel are qualified in the theory and application of the technologies involved in the research, development, testing, and evaluation of the proposed electronic system(s) and technology.
- (5) Schedule Realism\*: The offerors' abilities to aggressively pursue performance metrics in the shortest timeframe and to accurately account for that timeframe will be evaluated.
- (6) Cost Reasonableness and Realism\*: The objective of this criterion is to establish that the proposed costs are reasonable and realistic for the technical and management approach offered, as well as to determine the proposer's practical understanding of the effort. This will be principally measured by cost per labor-hour and number of labor-hours proposed. The evaluation criterion recognize that undue emphasis on cost may motivate proposers to offer low-risk ideas with minimum uncertainty and to staff the effort with junior personnel in order to be in a more competitive posture. DARPA discourages such cost strategies. Cost reduction approaches that will be received favorably include innovative management concepts that maximize direct funding for technology and limit diversion of funds into overhead.

\*Regarding schedule realism and cost reasonableness, proposals are required to define the time duration for each phase of the effort and associated cost per phase. Proposers are advised that given two proposals with acceptable schedule realism and cost reasonableness, the proposal with the most compressed schedule offering is preferred.

DARPA may solicit input on technical aspects of the proposals from non-government consultants or experts who are bound by appropriate non-disclosure requirements. Non-government technical consultants or experts will not have access to proposals labeled by their offerors as "Government Only."

Award(s) will be made to proposers whose proposals are determined to be the most advantageous to the Government, all factors considered, including the potential contributions of the proposed work to the overall research program and the availability of funding for the effort. Award(s) may be made to any proposer(s) whose proposal(s) is determined selectable regardless of its overall rating.

NOTE: PROPOSERS ARE CAUTIONED THAT EVALUATION SCORES MAY BE LOWERED AND/OR PROPOSALS REJECTED IF SUBMITTAL INSTRUCTIONS ARE NOT FOLLOWED.

As soon as the proposal evaluation is completed, the proposer will be notified of selectability or non-selectability. Selectable proposals will be considered for funding; non-selectable proposals will be destroyed. (One copy of non-selectable proposals may be retained for file purposes.) The Government reserves the right to select for award all, some, or none of the proposals received and to make awards without discussions. In the event that DARPA desires to award only portions of a proposal, negotiations will be opened with that proposer. All responsible sources capable of satisfying the Government's needs may submit a proposal which shall be considered by DARPA.

Proposals identified for funding may result in a procurement contract, grant, cooperative agreement or other transaction depending upon the nature of the work proposed, the required degree of interaction between parties, and other factors. The Government reserves the right to negotiate the type of award instrument determined appropriate under the circumstances. If warranted, portions of resulting awards may be segregated into pre-priced options.

The cost of preparing proposals in response to this announcement is not considered an allowable direct charge to any resulting contract or any other contract. Proposers are warned that only Contracting Officers are legally authorized to commit the Government.

## **10. Proposal Format and Submittal**

The form and format for proposals follows below. Proposals that do not satisfy these form and format requirements may be rejected without further review or evaluation. All submissions should be in the English language. Proposals should also be submitted electronically accompanied by a transmittal letter signed by an official who is authorized to commit the offeror. Proposals received by MTO but not submitted specifically to the BAA may be considered under the BAA at the Government's discretion.

All proposals must be in the format provided below. Nonconforming proposals may be rejected without review. Proposals shall consist of two volumes. All pages shall be printed on 8-1/2 by 11 inch paper with type not smaller than 12 point. Excel format and other graphic art or tables shall have type not smaller than 10 point. Volume I, Technical and Management Proposal, may include an attached bibliography of relevant technical papers or research notes (published and unpublished) that document the technical ideas and approach upon which the proposal is based. Copies of not more than three (3) relevant published papers can be included with the submission. The bibliography and attached papers are not included in the page counts given below. The submission of other supporting materials with the proposal is strongly discouraged and such materials will not be considered for review. Maximum page lengths for each section are shown in braces { } below.

## **11. Volume I, Technical and Management Proposal**

### **Section I. Administrative**

A. {1} **Cover sheet.** This should include: (1) BAA number; (2) Technical area; (3) Lead Organization Submitting proposal; (4) Type of business, selected among the following categories: "LARGE BUSINESS", "SMALL DISADVANTAGED BUSINESS", "OTHER SMALL BUSINESS", "HBCU", "MI", "OTHER EDUCATIONAL", or "OTHER NONPROFIT"; (5) Contractor's reference number (if any); (6) Other team members (if applicable) and type of business for each; (7) Proposal title; (8) Technical point of contact to include: salutation, last name, first name, street address, city, state, zip code, telephone, fax (if available), electronic mail (if available); (9) Administrative point of contact to include: salutation, last name, first name, street address, city, state, zip code, telephone, fax (if available), electronic mail (if available), total funds requested from DARPA, and the amount of cost-share (if any); and (10) Date proposal was prepared; (11) Proposal expiration date.

B. {1} **Official transmittal letter**

C. {1} **Table of Contents**

### **Section II. Executive Summary**

{3} This section should provide a clear and concise summary of the following:

- Innovative claims for the proposed programs that include a description of the unique technical solutions and approaches being proposed.
- Selected design drivers and photonic network designs
- Quantitative system-level benefits compared against future all-electrical network solutions
- Required photonic devices and comparison to current state-of-the-art
- Quantitative, end-of-program performance goals (device and link-level) and the key milestones associated with the development effort.

- Budget summary by task and year

### **Section III. Detailed Proposal Information**

- A. {15} **Technical Rationale & Approach.** This section should discuss the scientific and technical challenges in realizing an intrachip photonic communication network, along with proposed, innovative solutions to these challenges. This section should demonstrate that the proposer has a clear and comprehensive understanding of the state-of-the-art in microprocessor architecture, network architecture, and integrated photonic devices, and should provide sufficient technical details so as to permit complete evaluation of the feasibility of the proposed technical approach. This section must include, but is not limited to, a discussion of:
- a. Multiprocessor design driver characteristics
  - b. Detailed physical layout and logical description of photonic communication network designs
  - c. Performance analysis of the network designs (including, but not limited to, message latency, message latency distribution, bandwidth, and throughput as a function of load)
  - d. System-level benefits of the proposed approaches, and comparison to future, all-electrical network solutions
  - e. Optical-link power budgets and analyses
  - f. Total on-chip power dissipation for all functions related to intrachip photonic network and off-chip communication, including electrical control, photon loss, etc.
  - g. Device requirements and performance parameters necessary for realizing network designs
  - h. Proposed technical approaches for realizing required device performance (timeline and milestones will be in the next section)
  - i. End-of-program functional demonstrations, including link-level demonstrations of all critical devices/components working together, with a clear description of expected experimental measurements and performance goals.
- B. {7 + 1 for table} **Program Plan & Risk Assessment.** A narrative explaining the explicit timelines, milestone achievements, and quantitative metrics by which progress toward the proposed goals can be evaluated. This plan should include a specific and **detailed test plan** detailing how performance of milestones will be measured. The proposed period of performance of the overall program should be clearly stated. Milestones must be associated with demonstrable, quantitative measures of performance, and should be summarized in a single table. Regularly spaced, **measurable milestones should occur no more than six-month apart after start of the effort.** Additional measurable milestones should occur 2 months prior to end of Phase I and quantitative end-of-program goals should be clearly specified. This section should also identify major technical risk elements specific to the proposed approach, estimate the risk magnitude for each such element, and describe specific plans to mitigate risk. Proposers shall

clearly define all deliverables associated with the proposed research; all proprietary assertions to intellectual property of all types, including any background inventions, shall be set forth in detail. (See Volume 2, Section D, Intellectual Property.)

- C. {2} **Teaming & Management Plan.** A management plan that describes how the different members of the team will collaborate to demonstrate viable solutions to the program challenges.
- D. {5} **Capabilities.** A section describing relevant prior work, the background, qualifications and relevant experience of key individuals to be assigned to the program and the facilities and equipment to be utilized. Please do not attach supporting material (CDs, movies, etc.) to the proposal, except as noted in Section IV below.
- E. {5} **Slide Summary.** PowerPoint-type slides (i.e., landscape formatted for presentation) that succinctly highlight the major aspects of the proposal in a manner suitable for presentation to DARPA management. These must include an overview slide highlighting all the important aspects of the chosen design drivers and intrachip photonic communication designs, system-level benefits resulting from them, device challenges and the approach to meeting these challenges. Other slides should provide information such as, but not limited to, physical layout of intrachip photonic networks for the design drivers, communication link and other planned demonstrations, highlights of device concepts, approaches and goals, and highlights of system-level benefits. The notes section of slides may contain a concise discussion of the slide.
- F. {2} **Excel spreadsheet.** The first spreadsheet should contain the current state-of-the-art of devices, quantitative device milestones no more than 6 months apart after the start of the program, and the second spreadsheet should contain quantitative link demonstration milestones. Templates will be available on request.
- G. {5} **Statement of Work (SOW).** SOW written in plain English, outlining the scope of the effort by task area and phase and citing specific tasks to be performed, contractor requirements, and data and/or material deliverables.

#### **Section IV. Additional Information {Optional}**

- A. A brief bibliography of relevant technical papers and research notes (published and unpublished) which document the technical ideas upon which the proposal is based may be provided. Copies of not more than six (6) relevant papers can be included in the submission. This section does not count towards the overall page limit for Volume I.

#### **12. Volume II, Cost Proposal** {No page limit}

- A. Cover sheet, including (1) BAA number; (2) technical area; (3) lead organization submitting proposal; (4) type of business, selected among the following categories:

“Large Business,” “SDB,” “Other SB,” “HBCU,” “MI,” “Other Educational,” or “Other Nonprofit”; (5) contractor’s reference number (if any); (6) other team members (if applicable) and type of business for each; (7) proposal title; (8) technical point of contact, including salutation, last name, first name, street address, city, state, zip code, telephone, fax (if available), and electronic mail (if available); (9) administrative point of contact, including salutation, last name, first name, street address, city, state, zip code, telephone, fax (if available), and electronic mail (if available); (10) award instrument requested: cost-plus-fixed-fee (CPFF), cost-contract (no fee), cost-sharing contract (no fee), or other type of procurement contract (*specify*), or other transaction; (11) place(s) and period(s) of performance; (12) total proposed cost separated by basic award and option(s) (*if any*); (13) name, address, and telephone number of the offeror’s cognizant Defense Contract Management Agency (DCMA) administration office (*if known*); (14) name, address, and telephone number of the offeror’s cognizant Defense Contract Audit Agency (DCAA) audit office (*if known*); (15) date proposal was prepared; (16) proposal expiration date; and (17) the offeror’s Contractor and Government Entity (CAGE) Code, Dun and Bradstreet (DUN) Number, North America Industrial Classification System (NAICS) Number, and Tax Identification Number (TIN).

B. Detailed cost breakdown, including (1) total program cost broken down by major cost items (direct labor, subcontracts, materials, other direct costs, overhead charges, etc.) and further broken down by each phase and government fiscal year; (2) major program tasks by year; (3) an itemization of major subcontracts<sup>1</sup> and equipment purchases; (4) an itemization of any information technology (IT)<sup>2</sup> purchases; (5) a summary of projected funding requirements by month; and (6) the source, nature, and amount of any industry cost sharing. Where the effort consists of multiple portions that could reasonably be partitioned for purposes of funding, these should be identified as options with separate cost estimates for each.

C. Supporting cost and pricing information in sufficient detail to substantiate the summary cost estimates in B above. Include a description of the method used to estimate costs and supporting documentation. Note: “Cost or pricing data” as defined in FAR Subpart 15.4 shall be required if the offeror is seeking a procurement

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<sup>1</sup> To include similar cost breakdown as required by the offeror (prime).

<sup>2</sup> IT is defined as “any equipment, or interconnected system(s) or subsystem(s) of equipment that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information by the agency. (a) For purposes of this definition, equipment is used by an agency if the equipment is used by the agency directly or is used by a contractor under a contract with the agency which – (1) Requires the use of such equipment; or (2) Requires the use, to a significant extent, or such equipment in the performance of a service or the furnishing of a product. (b) The term “information technology” includes computers, ancillary, software, firmware and similar procedures, services (including support services), and related resources. (c) The term “information technology” does not include – (1) Any equipment that is acquired by a contractor incidental to a contract; or (2) Any equipment that contains imbedded information technology that is used as an integral part of the product, but the principal function of which is not the acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information. For example, HVAC (heating, ventilation, and air conditioning) equipment such as thermostats or temperature control devices, and medical equipment where information technology is integral to its operation, are not information technology.”

contract award of \$650,000 or greater, unless the offeror requests an exception from the requirement to submit cost or pricing data. Cost or pricing data is not required if the offeror proposes an award instrument other than a procurement contract (e.g. other transaction). Please also provide any Forward Pricing Rate Agreement, other such Approved Rate Information (e.g., Rate Memo's, etc.), or such other documentation that may assist in expediting negotiations (if not available, state so). **All proprietary subcontractor proposal documentation, prepared at the same level of detail as that required of the prime, of which cannot be uploaded to TFIMS shall be made immediately available to the Government, upon request, under separate cover (i.e., mail, electronic/email, etc.), either by the Proposer or by the subcontractor organization.**

#### D. Intellectual Property

##### 1. Procurement Contract Proposers

##### a. Noncommercial Items (Technical Data and Computer Software)

Proposers responding to this BAA requesting a procurement contract to be issued under the FAR/DFARS, shall identify all noncommercial technical data, and noncommercial computer software that it plans to generate, develop, and/or deliver under any proposed award instrument in which the Government will acquire less than unlimited rights, and to assert specific restrictions on those deliverables. Proposers shall follow the format under DFARS 252.227-7017 for this stated purpose. In the event that proposers do not submit the list, the Government will assume that it automatically has "unlimited rights" to all noncommercial technical data and noncommercial computer software generated, developed, and/or delivered under any award instrument, unless it is substantiated that development of the noncommercial technical data and noncommercial computer software occurred with mixed funding. If mixed funding is anticipated in the development of noncommercial technical data, and noncommercial computer software generated, developed, and/or delivered under any award instrument, then proposers should identify the data and software in question, as subject to Government Purpose Rights (GPR). In accordance with DFARS 252.227-7013 Rights in Technical Data - Noncommercial Items, and DFARS 252.227-7014 Rights in Noncommercial Computer Software and Noncommercial Computer Software Documentation, the Government will automatically assume that any such GPR restriction is limited to a period of five (5) years in accordance with the applicable DFARS clauses, at which time the Government will acquire "unlimited rights" unless the parties agree otherwise. Proposers are admonished that the Government will use the list during the source selection evaluation process to evaluate the impact of any identified restrictions, and may request additional information from the proposer, as may be necessary, to evaluate the proposer's assertions. If no restrictions are intended, then the proposer should state "NONE."

A sample list for complying with this request is as follows:

NONCOMMERCIAL			
Technical Data Computer Software To be Furnished With Restrictions	Basis for Assertion	Asserted Rights Category	Name of Person Asserting Restrictions
(LIST)	(LIST)	(LIST)	(LIST)

b. Commercial Items (Technical Data and Computer Software)

Proposers responding to this BAA requesting a procurement contract to be issued under the FAR/DFARS, shall identify all commercial technical data, and commercial computer software that may be embedded in any noncommercial deliverables contemplated under the research effort, along with any applicable restrictions on the Government’s use of such commercial technical data and/or commercial computer software. In the event that proposers do not submit the list, the Government will assume that there are no restrictions on the Government’s use of such commercial items. The Government may use the list during the source selection evaluation process to evaluate the impact of any identified restrictions, and may request additional information from the proposer, as may be necessary, to evaluate the proposer’s assertions. If no restrictions are intended, then the proposer should state “NONE.”

A sample list for complying with this request is as follows:

COMMERCIAL			
Technical Data Computer Software To be Furnished With Restrictions	Basis for Assertion	Asserted Rights Category	Name of Person Asserting Restrictions
(LIST)	(LIST)	(LIST)	(LIST)

2. Non-Procurement Contract Proposers – Non-commercial and Commercial Items (Technical Data and Computer Software)

Proposers responding to this BAA requesting a Technology Investment Agreement or Other Transaction for Prototype shall follow the applicable rules and regulations governing these various award instruments, but in all cases should appropriately identify any potential restrictions on the Governments use of any Intellectual Property contemplated under those award instruments in question. This includes both Non-commercial Items and Commercial Items. Although not required, proposers may use a format similar to that described in Paragraphs 1.a and 1.b above. The Government may use the list during the source selection evaluation process to evaluate the impact of any identified restrictions, and may request additional information from the proposer, as may be necessary, to evaluate the proposer’s assertions. If no restrictions are intended, then the proposer should state “NONE.”

### 3. All Proposers – Patents

Please include documentation proving your ownership of or possession of appropriate licensing rights to all patented inventions (or inventions for which a patent application has been filed) that will be utilized under your proposal for the DARPA program. If a patent application has been filed for an invention that your proposal utilizes, but the application has not yet been made publicly available and contains proprietary information, you may provide only the patent number, inventor name(s), assignee names (if any), filing date, filing date of any related provisional application, and a summary of the patent title, together with either: 1) a representation that you own the invention, or 2) proof of possession of appropriate licensing rights in the invention.

### 4. All Proposers-Intellectual Property Representations

Please provide a good faith representation that you either own or possess appropriate licensing rights to all other intellectual property that will be utilized under your proposal for the DARPA program. Additionally, offerors shall provide a short summary for each item asserted with less than unlimited rights that describes the nature of the restriction and the intended use of the intellectual property in the conduct of the proposed research.

## **13. Security Information**

The Government anticipates that proposals submitted under a BAA will be *unclassified*. In the event that a proposer chooses to submit a classified proposal or submit any documentation that may be classified, the following information is applicable.

Security Classification guidance on DD Form 254 will not be provided at this time since DARPA is soliciting ideas only. After reviewing the incoming proposals, if a determination is made that the award instrument may result in access to classified information, a DD Form 254 will be issued and attached as part of the award.

Proposers choosing to submit a classified proposal must first receive permission from the Original Classification Authority to use their information in applying to this BAA. An applicable classification guide should be submitted to ensure that the proposal is protected appropriately.

Classified submissions shall be in accordance with the following guidance:

**Collateral Classified Data:** Use classification and marking guidance provided by previously issued security classification guides, the Information Security Regulation (DoD 5200.1-R), and the National Industrial Security Program Operating Manual (DoD 5220.22-M) when marking and transmitting information previously classified by another original classification authority. Classified information at the Confidential and Secret level may only be mailed via U.S. Postal Service (USPS) Registered Mail or U.S. Postal Service Express Mail (USPS only; not DHL, UPS or FedEx). All classified information will be enclosed in opaque inner and outer covers and double wrapped. The inner envelope shall be sealed and plainly marked with the assigned classification and addresses of both sender and addressee. The inner envelope

shall be addressed to:

Defense Advanced Research Projects Agency (DARPA)  
ATTN: BAA 07-35, DARPA/MTO, Dr. Jagdeep Shah  
3701 North Fairfax Drive, Suite 516  
Arlington, VA 22203-1714

The outer envelope shall be sealed with no identification as to the classification of its contents and addressed to:

Defense Advanced Research Projects Agency (DARPA)  
Security & Intelligence Directorate, Attn: CDR  
3701 North Fairfax Drive, Suite 255  
Arlington, VA 22203-1714

All Top Secret materials should be hand carried via an authorized, two-person courier team to the DARPA Classified Document Registry (CDR).

Special Access Program (SAP) Information: Contact the DARPA Special Access Program Central Office (SAPCO) at 703-526-4052 for further guidance and instructions prior to transmitting to DARPA. All Top Secret SAP, must be transmitted via approved methods for such material. Consult the DoD Overprint to the National Industrial Security Program Operating Manual for further guidance. It is strongly recommended that you coordinate the transmission of SAP material and information with the DARPA SAPCO prior to transmission.

Sensitive Compartmented Information (SCI) Data: Contact the DARPA Special Security Office at 703-812-1984/1994 for the correct SCI courier address and instructions. All SCI data must be transmitted through your servicing Special Security Officer (SSO). All SCI data must be transmitted through SCI channels only (i.e., approved SCI facility to SCI facility via secure fax).

Proposers must have existing and in-place prior to execution of an award, approved capabilities (personnel and facilities) to perform research and development at the classification level they propose.

Proprietary Data: All proposals containing proprietary data should have the cover page and each page containing proprietary data clearly marked as containing proprietary data. It is the proposer's responsibility to clearly define to the Government what is considered proprietary in nature.

In addition, the International Traffic in Arms Regulation (ITAR) may apply and should be considered in each proposal. Additional ITAR information is available at [http://www.pmdtc.org/itar\\_index.htm](http://www.pmdtc.org/itar_index.htm). If a question exists regarding ITAR, please contact [SID\\_International\\_Security@darpa.mil](mailto:SID_International_Security@darpa.mil). Information pertaining to the Export Administration Regulation (EAR) is available at [http://www.gpo.gov/bis/ear/ear\\_data.html](http://www.gpo.gov/bis/ear/ear_data.html).

If you choose to submit a classified proposal protected by other than DARPA, you must first receive permission of the Original Classification Authority (OCA) to use their information in replying to this BAA and submit the applicable OCA classification guide(s) to ensure that the proposal is protected properly.

#### **14. Procurement Integrity, Standards of Conduct, Ethical Considerations, and Organizational Conflicts of Interest (OCI)**

Certain post-employment restrictions on former federal officers and employees may exist, including special government employees (including but not limited to Sections 207 and 208 of Title 18, United States Code, the Procurement Integrity Act, 41 U.S.C. 423, and FAR 3.104), and other ethical rules for government employees may indicate conflicts of interest with respect to some proposers under this BAA. Prior to the start of proposal evaluations, the Government will assess whether any potential conflict of interest exists in regard to the DARPA Program Manager as well as those individuals chosen to evaluate proposals received under this BAA. The DARPA Program Manager for this solicitation is not an Intergovernmental Personnel Act (IPA) assignment.

All proposers and proposed subcontractors must affirm whether they are providing scientific, engineering, and technical assistance (SETA) or similar support to any DARPA technical office(s) through an active contract or subcontract, including those contracts being managed by outside DARPA contracting agents. All affirmations must state which office(s) the proposer supports and identify the prime contract numbers. Affirmations shall be furnished at the time of proposal submission. All facts relevant to the existence or potential existence of OCIs (FAR 9.5.) must be disclosed. The disclosure shall include a description of the action the proposer has taken or proposes to take to avoid, neutralize, or mitigate such conflict (e.g., mitigation plan).

Should the Government determine that a potential OCI exists for which the offeror did not provide a mitigation plan, such plan may be requested by the Government during proposal evaluation(s). If the situation cannot be mitigated by the contractor, or if the Government determines some other ethical conflict exists for the Program Manager that cannot effectively be resolved, the proposal may be returned without technical evaluation and withdrawn from consideration for award under this BAA.

Any contract resulting from this solicitation will include terms and conditions that require contractors to accept disclosure restrictions imposed by any future classification of proposed technology.

#### **15. Human Use**

Proposals selected for funding are required to comply with provisions of the Common Rule (32 CFR 219) on the protection of human subjects in research (<http://www.dtic.mil/biosys/downloads/32cfr219.pdf>) and the DoD Directive 3216.2 (<http://www.dtic.mil/whs/directives/corres/html2/d32162x.htm>). All proposals that involve the use of human subjects are required to include documentation of their ability to follow federal guidelines for the protection of human subjects. This includes, but is not limited to, protocol approval mechanisms, approved Institutional Review Boards (IRB), and federal-wide assurances. These requirements are based on expected human use issues during the entire length of the proposed effort.

For proposals involving “greater than minimal risk” to human subjects within the first year of the project, performers must provide evidence of protocol submission to a federally approved IRB *at the time of final proposal submission to DARPA*. For proposals forecasted to involve greater than minimal risk after the first year, a discussion on how and when the proposer will comply with submission to a federally approved IRB must be provided in the proposal. More information on applicable federal regulations can be found at the Department of Health and Human Services—Office of Human Research Protections website (<http://www.dhhs.gov/ohrp/>).

## **16. Public Release or Dissemination of Information**

The following provision will be incorporated into any resultant contract:

(a) There shall be no dissemination or publication, except within and between the Contractor and any subcontractors, of information developed under this contract or contained in the reports to be furnished pursuant to this contract without prior written approval of the DARPA Technical Information Officer (DARPA/TIO). All technical reports will be given proper review by appropriate authority to determine which Distribution Statement is to be applied prior to the initial distribution of these reports by the Contractor unless otherwise instructed by the contract. Papers resulting from unclassified contracted fundamental research are exempt from prepublication controls and this review requirement, pursuant to DoD Instruction 5230.27 dated October 6, 1987.

(b) When submitting material for written approval for open publication as described in subparagraph (a) above, the Contractor must submit a request for public release request to the DARPA TIO and include the following information: 1) Document Information: document title, document author, short plain-language description of technology discussed in the material (approx 30 words), number of pages (or minutes of video) and document type (briefing, report, abstract, article, or paper); 2) Event Information: event type (conference, principle investigator meeting, article or paper), event date, desired date for DARPA's approval; 3) DARPA Sponsor: DARPA Program Manager, DARPA office, and contract number; and 4) Contractor's Information: POC name, e-mail and phone. Allow four weeks for processing; due dates under four weeks require a justification. Unusual electronic file formats may require additional processing time. Requests can be sent either via e-mail to [tio@darpa.mil](mailto:tio@darpa.mil) or via 3701 North Fairfax Drive, Arlington VA 22203-1714, telephone (571) 218-4235. Refer to [www.darpa.mil/tio](http://www.darpa.mil/tio) for information about DARPA's public release process.

## **17. Export Licenses**

The following provision will be incorporated into any resultant contract:

(1) The contractor shall comply with all U. S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in the performance of a resulting contract. In the absence of available

license exemptions/exceptions, the Contractor shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports (including deemed exports) of hardware, technical data, and software, or for the provision of technical assistance.

(2) The Contractor shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of this contract, including instances where the work is to be performed on-site at any Government installation (whether in or outside the United States), where the foreign person will have access to export-controlled technical data or software.

(3) The Contractor shall be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions/exceptions.

(4) The Contractor shall be responsible for ensuring that the provisions of this clause apply to its subcontractors.

## **18. Subcontracting**

Pursuant to Section 8(d) of the Small Business Act (15 U.S.C. 637(d)), it is the policy of the Government to enable small business and small disadvantaged business concerns to be considered fairly as subcontractors to contractors performing work or rendering services as prime contractors or subcontractors under Government contracts, and to assure that prime contractors and subcontractors carry out this policy. Each proposer who submits a contract proposal and includes subcontractors is required to submit a subcontracting plan IAW FAR 19.702(a) (1) and (2) should do so with their proposal. The plan format is outlined in FAR 19.704. {Shall be included as part of Volume II}

## **19. Confidentiality**

It is the policy of DARPA to treat all proposals as competitive information and to disclose their contents only for the purpose of evaluation. No proposals will be returned. The original of each proposal received will be retained at DARPA and all other copies of non-selected proposals destroyed. Documentation related to the source selection process will be marked SOURCE SELECTION INFORMATION – SEE FAR 2.101 AND 3.104.

## **20. Award Administration Information**

(1) Central Contractor Registration. Selected proposers not already registered in the Central Contractor Registry (CCR) will be required to register in CCR prior to any award under this BAA. Information on CCR registration is available at <http://www.ccr.gov>.

(2) Representations and Certifications. In accordance with Federal Acquisition Regulation 4.1201, prospective proposers shall complete electronic annual representations and certifications at <http://orca.bpn.gov>.

(3) Wide Area Work-Flow (WAWF). Unless using another approved electronic invoicing system, performers will be required to submit invoices for payment directly via the Internet/WAWAF at <http://wawf.eb.mil>. Registration to WAWF will be required prior to any award under this BAA.