ARCADE – Artificial Reasoning for Circuit Automation and Design Engineering

1. **Program Overview**

   ARCADE transforms and accelerates electrical circuit design within the Intelligence Community (IC) by leveraging Artificial Intelligence (AI) to develop an intelligent, comprehensive AI-knowledge assistant that extracts key information from vast technical documentation and enables engineers to perform quick, intuitive queries to meet the speed of mission.

   The technical information ingested by ARCADE will include text, datasheets, diagrams, schematics, tables, and graphs. ARCADE extracts crucial details about electrical components, their specifications and interfaces to compile them into a comprehensive searchable knowledge platform.

   Going beyond a simple search engine, ARCADE aims to suggest and recommend components based on design requirements, constraints, and performance parameters. This capability enables engineers to perform swift, targeted queries, dramatically reducing the time it takes to find, compare, and select suitable parts. It also aims to help identify optimal components and potential alternatives more efficiently than manually sifting through thousands of documents. Ultimately, ARCADE will lead to faster, more accurate, and more robust circuit designs, ensuring government missions can be deployed with unprecedented speed and reliability.

2. **Objectives**

   Successful ARCADE solutions must perform all three task areas. While proposals that prioritize automation will be viewed more favorably, automation needs to be balanced with transparency and observability. Some manual human involvement is expected.

   Task Area 1 (TA1): Intelligent Data Ingestion and Interpretation.
   Must be capable of quickly ingesting and interpreting large corpora of complex technical documents, such as component datasheets, technical manuals, tables, graphs and schematics in different formats, such as PDFs and images. This involves interpreting and encoding complex specifications – such as voltage ratings, efficiency curves, and package size – into a knowledge base. It should be possible to incrementally update the resulting knowledge base (e.g., to add new versions of a datasheet or remove obsolete information).

   Task Area 2 (TA2): Intelligent Query and Retrieval

Processes and transforms raw data into an indexed format optimized for intelligent, context-aware queries. This involves using advanced AI and machine learning to interpret and encode complex specifications—such as voltage ratings, efficiency curves, and package size. This task may include the design of an Application Programming Interface (API) to lookup the knowledge base with circuit design context (which can include design parameters or information about other components in the design). The results will rapidly suggest components that meet performance parameters, along with citations to the corresponding datasheets. The query may also use interpolation of data (for example, "efficiency curves of a voltage regulator").

Task Area 3 (TA3) Intelligent Assistant for Component Selection

Create an intuitive UI (chat interface) for the TA2 capability that integrates into existing engineering workflows. The chat UI should intelligently search for processed data from TA2, using both natural language and specific design parameters to rapidly suggest components, including citations, that meet performance parameters. It should also provide an easy way for the user to specify or include the design context (e.g., design parameters, constraints), enter the query and review the citations. The UI may be standalone and does not need to be integrated with any electronic design automation (EDA) tools.

3. **Program Scope and Limitations**

Proposals shall explicitly address the following:

- Approaches that intelligently process technical documents to extract key information about electrical components, while minimizing the overall financial expenditure.
- Approaches which recognize and digitize parameters from both text and graphical representations.
- Approaches which implement a scalable backend to support complex relationships between components and their specifications, enabling sophisticated querying.
- Research which accelerates design workflow for component selection.
- Software solutions which provide an intuitive interface for engineers to leverage.
- Approaches which automate workflow for ingesting additional technical documents into the knowledge base.
- Transition: Performer shall identify how their proposed solution for TA1, TA2, and TA3 may be adapted to work in a closed network.
- Underlying theory: Proposed strategies to meet program-specified metrics must have firm theoretical bases that are described with enough detail that reviewers will be able to assess the viability of the approaches. Proposals shall properly describe and reference previous work upon which their approach is founded.
- Research & Development approach: Proposals shall describe the technical approach to meeting program metrics.

- Technical risks: Proposals shall identify technical risks and proposed mitigation strategies for each identified risk.
- Software development: Proposals shall describe the approach to software architecture, modularization, and integration. If the Performer leverages backbone language models, the ability to "switch out" and retrain using future language model releases is highly desirable.

The following areas of research are out of scope for the ARCADE program:

- Research that does not have strong theoretical and experimental foundations.
- Approaches that require significant manual effort.
- Approaches that address component placement, and Printed Circuit Board (PCB) layout.
- Development of hardware.
- Research that utilizes proprietary data that restricts the Government's ability to transfer the technology or data.
- Approaches that consist merely of integrating currently existing software.

4. **Program Specific Terms/Definitions**
   Datasheet: In the context of electronic design, a datasheet for a specific component (like a resistor or an integrated circuit) provides critical information such as its electrical ratings, pin configuration, and operating conditions, which are essential for its proper use in a circuit.

5. **Human or Animal Subject Research applicable to this Program?**
   None

6. **Government Furnished Equipment/Information?**
   Government will be providing an initial component library and technical documentation for ingestion and extraction. Performers are welcome and encouraged to add to this throughout the program.

7. **Program Metrics**
   Delivered software will be evaluated by an independent Test and Evaluation (T&E) team on sequestered evaluation datasets in a closed compute environment.

   The metrics below are preliminary and may be modified by the Government. Proposers are encouraged to suggest additional metrics and evaluation constructs based on their approach and expertise. Metric scores will be calculated by the Test and Evaluation

Team. The test set (component library) will contain a variety of passive, active, and electromechanical components.

a) Intelligent Data Ingestion and Interpretation

The ability to accurately and efficiently ingest technical documentation automatically.

a. **Accuracy of Data Extraction:** Measure the percentage of key data points (e.g., component values, electrical specifications, mathematical formulas, and graphs) correctly extracted from datasheets and diagrams.
b. **Size of corpus ingested:** The total size of the corpus that can be effectively ingested by the system.
c. **Diversity of technical material:** The number of different kinds of technical information that are intelligently interpreted and ingested (e.g., text, tables, charts, schematics, component values, electrical specifications, mathematical formulas, and graphs). Adaptability to new types of components, data fields, and interconnectivity will be viewed favorably.
d. **Optimization:** Minimize document processing time, while minimizing token consumption and operational costs.
    i. **Efficiency of data ingestion:** The average time in seconds to add a technical document to the knowledge base.
    ii. **Efficiency of data update:** The average time in seconds to update the knowledge base with a revised version of a technical document.
    iii. **Quality adjusted throughput:** The average time to update required to add a technical document to the knowledge base, multipled by (1 – Defect Rate). The Defect Rate is the proportion of required fields that are incorrectly extracted, normalized, or validated during ingestion.

b) Intelligent Query and Retrieval

The ability to intelligently retrieve information from the knowledge base.

a. **Time to Search:** The time it takes to process a search query and provide results, while minimizing operational cost.
b. **Interpolation Error:** For queries that require numerical reasoning (or interpolation) between known information to drive a new answer, the relative error between the true answer and the generated answer.
c. **Precision@k:** Given a user query with context, the proportion of relevant items within the top K retrieved results. This provides a quality measurement of the results.
d. **Recall@k:** Given a user query with context, the proportion of all relevant items within the top K retrieved results. This provides a measure of completeness from the results.

c) Intelligent Assistant for Component Selection and Query.

Measuring accuracy and time to provide trustworthy component recommendation for electrical design engineers using natural language and/or keyword search queries. Utility measured by both efficiency and trust metrics.

a. **Time to Search:** Track the time it takes to process a search query and provide results, while minimizing operational cost.
    i. **Reduced Time on Task:** The percent reduction in time to complete a task when using Intelligent Assistant.

b. **Semantic Accuracy:** Assess the percentage of user-provided specifications (e.g., "output voltage should be 5V," "low power consumption") that correctly interprets and applies to the user input.

c. **Trust Interaction Score:** A weighted average of Transparency, Observability, and Adaptability. Designed to capture how well an intelligent assistant explains its recommendations, allows users to audit decision trails, and incorporates human feedback.

i. **Transparency:** The percentage of recommendations with clear rationale and traceable sources

ii. **Observability:** The percent of recommendations where the decision trail can be reviewed and audited by the user

iii. **Adaptability:** The percent score derived from how quickly the system aligns with user feedback, calculated as one minus the ratio of the average number of iterations required to the maximum allowed iterations.

8. Program Waypoints, Milestones, Deliverables

ARCADE is a 12-month program comprised of two 6-month phases to evaluate performers' progress to meet the program metrics. Table 1 shows a timeline for the program with Government-defined milestones and deliverables

Table 1: Program Waypoint, Milestone and Deliverables Testing Timeline

Event	Months after Kick-off		Deliverables
	Phase 1	Phase 2	
Program Wide Milestone Kickoff	1	6	Read-ahead package due from Performers to the Government 7 days before meeting. If required by the PM, updates after the meeting are due 15 days after the meeting date.
Technical Review Meetings	Every 2 Weeks	Every 2 Weeks	Read-ahead package due from Performer to the Government 1 day before meeting. If required by the PM, updates after the meeting are due 7 days after the meeting date.
Site Visits and Waypoint Review	3, 5	8, 10	Site visits (to be held concurrently with Technical Review Meetings)

Event	Months after Kick-off		Deliverables
	Phase 1	Phase 2	
Software Deliverables	5	11	Source code, build scripts and documentation for facilitating reproduction of system operation by an independent Test and Evaluation Team. Deliverables shall be received at the T&E site specified by the Government no later than the final day of the listed month. Performers shall also provide documentation and training to the Government for proper usage.
Final Technical Report	6	12	Performers shall provide a final technical report at the end of each phase outlining their technical progress, methodology, challenges, successes, and recommendations for future efforts. A draft final report is to be delivered 2-4 weeks prior to the deadline.
Independent T&E	6	12	Upon receipt of the deliverables, T&E will be conducted. Performers may expect test results within one month of submission.
Financial and Technical Reports	Monthly	Monthly	Monthly financial and technical reports are due by the 10th day of the following month.
Collaborative Transition Workshop		12	A Collaborative Transition Workshop held in the DC area at the end of Program
End of Phase	6	12	Phase Period of Performance Ends

9. Software Deliverable Formatting

Performers will be required to provide algorithms, software deliverables, design documentation, and operating instructions to execute the automated software in a manner that conforms to a standardized industrial method or methods that will be provided at program Kickoff. To facilitate planning, Offerors may assume that the standardized configuration will require the use of software containerization technology (e.g., Docker or Kubernetes). This means that the entirety of a Performer's system, including pre- and post-processing, must be included within the delivered software container. For models that require training, the expectation is for the initial model training to occur on Performer systems, with the ability for the T&E Team to re-train and test the model with the same and/or other data. Performers shall also provide source code to the government and T&E team to enable modification of Performer containers to suit deployment constraints. Offeror teams that do not include the requisite expertise to conduct such software development shall include costs in their proposal to obtain software development support.

Each team is required to include among their key personnel a Lead System Integrator (LSI) who shall be responsible for preparing software Deliverable subcomponents, modules, and

systems, performing quality control of Deliverable, and integrating key components into the primary ARCADE system(s). The LSI will also oversee communication and coordination across a Performer's research teams including subcontractors, if applicable, to ensure research products are functional and following software coding best practices (e.g., inline comments, documentation). Additional team members and roles are dependent on the proposed research; there is no predetermined or required skill mix.

10. Place of Performance

Performance will be conducted at the Performers' approved sites with Government's concurrence.

11. Test & Evaluation

T&E will be conducted by an independent team of Government and contractor staff carrying out evaluation and analyses of Performer Deliverables using program test datasets and protocols. In addition to independent T&E, the program will regularly gauge interim progress of Performer research activities towards ARCADE objectives and target metrics using T&E results measured and reported by the Performer teams themselves. Evaluations will occur during M6 and M12 that will exercise performer solutions across technical challenges.

Performers are encouraged to develop methodologies for a self-contained / self-hosted environment for use by government transition partners on their own network/systems. Proposals must specify the processing dependencies needed to carry out the proposed research and what architecture and library characteristics are necessary for their approach(es) to be successful at meeting program objectives. Performers will have specific Deliverable Milestones at which all subcomponent and system algorithms and software will be delivered to IARPA and its designated T&E Team. The T&E Team will then conduct evaluations at the direction of the ARCADE PM and with the objective of characterizing the quality, functionality, and performance of the ARCADE Deliverables. In addition to quantitative measurements, T&E will be carried out to establish a thorough understanding of the progress, status, and limitations of the Performer's research. T&E results and feedback will be provided to Performers at regular intervals to keep them abreast of current independent performance measurements and to inform and improve their R&D approaches and methods. T&E results from all Performers will be shared with all teams to establish an understanding of the current state and progress of ARCADE research; T&E results will also be shared with USG external stakeholders, including their contractors, for Government purposes.

12. Technical Exchange Meetings/Workshops/Site Visits/Travel Requirements

Performers are expected to assume responsibility for administration of their projects and to comply with contractual and program requirements for reporting, attendance at program workshops, and availability for site visits. The following paragraphs describe typical

expectations for meetings and travel for IARPA programs as well as the contemplated frequency and locations of such meetings. In addition to ensuring that all necessary details of developed software, algorithm, and operational instructions are clear and complete, each Performer will be required to be available for questions and troubleshooting from the T&E Team during bi-weekly status meetings.

All Performer teams are expected to attend a collaborative workshop, to include Key Personnel from prime and subcontractor organizations. The workshop will focus on technical aspects of the program and on facilitating open technical exchanges, interaction, and sharing among the various program participants. Program participants will be expected to present the technical status and progress of their efforts to other participants and invited guests.

Site visits by the Government Team will generally take place at M3 and M8 during the life of the program. These visits will occur at the Performer's facility. Reports on technical progress, details of successes and issues, contributions to the program goals, and technology demonstrations will be expected at such site visits.

13. Anticipated Timeline

ARCADE is a 12-month program with two 6-month phases to evaluate performers' progress toward meeting the program metrics.

Phase I: Performers will be evaluated based on Phase 1 Metrics during M6 of the program.

Phase II: Performers will be evaluated based on Phase 2 Metrics during M12 of the program.