ICECool Abstract Q&A

Q1. When submitting an abstract for DARPA-BAA-12-50 should the PI register and submit through T-FIMS or can I, as the research administrator, register and submit for the PI through T-FIMS?

A1. The administrator can register and submit for the PI through T-FIMS.

Q2. The BAA seems highly directed to two-phase microchannel approaches. I would like to consider an alternative approach such as use of the Joule-Thomson effect. Would doing so be considered compliant?

A2. Proposals need to address all five areas described on Page 7 of the BAA, which includes "Design and fabrication of stable, high exit quality evaporative microfluidic cooling systems capable of providing a minimum 1 kW/cm^2 heat flux and 1 kW/cm^3 heat density removal across a chip and/or chip stack without exceeding commonly accepted process and device operating temperature limits." Proposals should follow the Instructions for Proposers section on pages 8-10, the Program Structure and Metrics section on page 11, and the Modeling, Simulation, Test Plan, and Sensitivity Analysis section on page 12.

Q3. Are we restricted to flow boiling or can micro heat pipe type configurations be considered?

A3. Micro heat pipe configurations could certainly be part of an ICECool approach, but as stated proposals need to address all five areas described on Page 7 of the BAA, which includes "Design and fabrication of stable, high exit quality evaporative microfluidic cooling systems capable of providing a minimum 1 kW/cm^2 heat flux and 1 kW/cm^3 heat density removal across a chip and/or chip stack without exceeding commonly accepted process and device operating temperature limits."

Q4. Is water or water based fluid acceptable as a heat transfer media?

A4. On page 9 of the BAA it states, "Proposals should detail the approach to achieve evaporative dielectric cooling".

Q5. What is the area associated with the 1 kW/cm^2 minimum flux requirement?

A5. The proposer is to define all chip and microchannel dimensions as stated on page 9 of the BAA.

Q6. Is the minimum flux requirement a local surface to transport media requirement or a flow direction requirement?

A6. On page 9 of the BAA it states, "Additional discussion of the proposed heat removal technique includes the heat flux removed (kW/cm^2)" and Table 1 on page 11, sets this metric as greater than 1 kW/cm^2.

Q7. The usual temperature requirement for silicon devices is around 60 ^{0}C. Is this what is intended here?

A7. On page 7 it states, "Design and fabrication of stable, high exit quality evaporative microfluidic cooling systems capable of providing a minimum 1 kW/cm^2 heat flux and 1 kW/cm^3 heat density removal across a chip and/or chip stack without exceeding commonly accepted process and device operating temperature limits." Thus it is the proposer's responsibility to define the envisioned electronic device and then justify that the cooling solution remains inside the device's operating temperature limits. The envisioned device should also be reflected in design of the test vehicle.

Q8. Is the program goal a closed-loop operation where the coolant is recirculated? If it is a closed-loop operation (as expected in real applications), should we address the heat rejection and condensation of the coolant?

A8. It is a requirement to fully define the cooling loop, but extensive condenser development is outside the scope of this BAA. Proposers can also refer to page 10 which states, "Finally, proposers should describe any off-chip components employed in the cooling loop, including micro- or macro-pumps, chillers, reservoirs, condensers, valves, or other devices. Please note that pump development is outside the scope of this BAA."

Q9. Does the coolant pumping have to be self-driven (i.e. thermal-mechanically driven by the chip heat)? Is external electrically driven pump acceptable?

A9. Page 10 of the BAA sets the requirements related to pumps by stating, "Finally, proposers should describe any off-chip components employed in the cooling loop, including micro- or macro-pumps, chillers, reservoirs, condensers, valves, or other devices. Please note that pump development is outside the scope of this BAA."

Q10. If a single phase coolant can meet the performance requirement, do we still have to incorporate evaporative cooling in our solution?

A10. Evaporative cooling must be incorporated in order to meet all metrics stated in Table 1 on page 11 of the BAA. Also, see A2.

Q11. In order for us to gage the scope of our proposal, could you please provide some guidance as to the expected level of funding?

A11. Please see Section II Award Information, of the ICECool BAA. "The amount of resources made available under this BAA will depend on the quality of the proposals received and the availability of funds." No specific program funding information will be provided.

Q12. We were going to team with company X and a company called Y. X opted out for tactical reasons. We need Y because they have the heat transfer problem and the knowledge of what one can and cannot do to their devices. Are they an acceptable team partner?

A12. Please see Section III: Eligibility Information, of the ICECool BAA. "Collaborative efforts or teaming are encouraged."

Q13. In the BAA, it mentioned "evaporative cooling" as a concept to cool the high power chip (1 kW/cm^2). Is this a requirement? Can we use other methods if we can achieve the same results as stated in the BAA?

A13. Evaporative cooling must be incorporated in order to meet all metrics stated in Table 1 on page 11 of the BAA. Also, see A2 and A10.

Q14. Does this BAA focus more on innovative design or the actual fabrication processes?

A14. The focus of the BAA is a stated in the BAA. We do expect that in order to meet all program metrics this would involve innovative design and the ability to realize said design with actual fabrication processes.

Q15. What is the funding range for each proposal? Is there a ceiling for the proposal?

A15. Please see Section II Award Information, of the ICECool BAA. "The amount of resources made available under this BAA will depend on the quality of the proposals received and the availability of funds." No specific program funding information will be provided.

Q16. Can tell me if my specific chip stack configuration meets the 1 kW/cm^2 and 1 kW/cm^3 requirements?

A16. The specific approach is determined by the proposer. However, proposers should remember to follow the statement on page 6, "DARPA expects proposers to define and demonstrate intrachip and interchip thermal management approaches that will substantially reduce or remove the thermal limitations to device performance while also reducing the size and weight of the thermal solution and the electronic system as a whole". Proposals should also follow the ICECool Fundamentals Scope on pages 6 and 7 of the BAA as well as the Instructions for Proposers section on pages 8-10, and the Program Structure and Metrics section on page 11. Also, feedback on proposed approaches will be given following the Abstract Phase.

Q17. I have been working to develop a fluid cooling technology. Potential benefits would be x, y, and z. For the initial research, my target would be board-scale. It sounds

to me that your interests lie within the realm of chip scale. Will this topic be a match for this project?

A17. Proposals need to address all five areas described on Page 7 of the BAA. This includes the following statement, "Design and fabrication of stable, high exit quality evaporative microfluidic cooling systems capable of providing a minimum 1 kW/cm^2 heat flux and 1 kW/cm^3 heat density removal across a chip and/or chip stack." See also A2 and A10.

Q18. Can you please clarify whether or not a cover page should be included with the Abstract Proposal for BAA-12-50? The BAA says to include only section II of Volume I, which would eliminate the cover page. Then the BAA says that the cover sheet should be clearly marked Abstract.

A18. Section IV: Application and Submission Information of the ICECool BAA states that the abstracts should follow the same general format as described for Volume I under PROPOSAL FORMAT, but include ONLY Section II. This does include Section I Administration, but says the proposer should not include Section III Detailed Proposal Information.

Q19. Do ICECool Fundamentals proposals need to achieve all metrics as stated in Table 1 on page 11?

A19. ICECool Fundamentals proposals need to achieve ALL metrics as stated in Table 1 on page 11. It is also highly recommended that the proposed intermediate and final program milestones be listed in a tabular format similar to that of Table 1, so that the government can easily compare proposed milestones with program metrics.

Q20. Do ICECool Fundamentals proposals need to contain an actual thermofluid model as indicated on page 12 of the BAA?

A20. Yes, as stated on page 12 of the BAA, "ICECool Fundamentals proposals must contain a comprehensive thermofluid model of the intra- or interchip cooled demonstration vehicle. This model should embody the ICECool techniques selected by the proposing team to establish the efficacy of the approach and enable a sensitivity analysis of the design concept with emphasis on the variability introduced by microfabrication techniques and inherent variability of two-phase processes". Furthermore, the model should support why proposer believe they can achieve the program metrics as stated in Table 1 on page 11. Proposers can also refer to additional text regarding the modeling that was added in revision of the BAA posted on 19 July on pages 7 and 10.

Q21. Do ICECool Fundamentals proposals need to include a test plan for all of the metrics in Table 1 on page 11?

A21. Yes, as stated on page 12 of the BAA, "Proposals must also contain a comprehensive test plan for the intra- or interchip cooled demonstration vehicle. Proposers should detail all the empirical measurements, including the expected accuracy of the sensors and techniques and any supporting electro-thermal modeling and simulation efforts, needed to establish that the demonstration vehicle meets all metrics in Table 1. Measurement error is expected to be less than 10% of the stated value".

Q22. Do ICECool Fundamentals proposals need to have at minimum an intermediate and final test demonstration?
A22. Yes, this is stated on both page 11 and page 12 of the BAA. These demonstrations should be clearly described in the proposal.

Q23. Do ICECool Fundamentals proposals need to include a plan for establishing the thermal limits, physics of failure, and reliability of the proposed cooling approach?
A23. As stated on page 7 in point vi, it is necessary for proposals to address the "Characterization of the thermal performance limits and physics-of-failure of the proposed high heat density, on-chip, cooling technologies", and as stated on pages 10 and 11, "Proposals should establish the reliability of the proposed cooling approach". Thus, ICECool proposals need to take care to address these requirements. This should be framed around the metrics associated with Reliability in Table 1. This would include the following five items in the full proposal:

1. A thorough description of the Physics of Failure with the metric being induced functional failures in the chip.
2. The proposer defined erosion and corrosion (μm/year) under the expected hydrodynamic flow rates.
3. The design and plan for demonstrating the failure free operation of the thermal components for 10^3 cycles.
4. The design and plan for demonstrating the failure free operation of the thermal system for 10^2 hours.
5. The design and justification for why the proposer believes the thermal components in their proposed cooling system will be able to achieve a mean time to failure (MTTF) of 10^4 hours or greater, using the description of the physics of failure and the testing described above as evidence of this.

Q24. Do ICECool Fundamentals proposals need to justify the proposer's ability to perform the microfabrication tasks necessary to fabricate their cooling system and test vehicles?
A24. As stated on page 7 in point iii, it is necessary for proposals to address "Microfabrication of high aspect ratio microchannels and/or micropores in a relevant electronic material (Si, SiC, AlN, diamond, or other as appropriate) as well as integration of micro-"fittings," such as microvalves, micropores, and fluid connectors, as needed". In order for the proposer to demonstrate that they have the necessary capability and understanding of how to do this, the proposer must justify that they not only have the ability to etch microchannels and make microvalves, they must also clearly identify the process steps for how the cooling system will be microfabricated and assembled, which for each step must include the proposer's experience in that fabrication and/or bonding

technique, and the thermal budget, so as to demonstrate that the assembly will be compatible with the intended electronic application. For example, a process step that would require 1100 ^{0}C would not be acceptable if in a real application the actual electronic device would already be present. Proposals that do not contain a thorough description of their microfabrication capability and process flow will be considered non-responsive.

Q25. For the Delta T across heated chip < 10 K metric, does this imply the temperature rise permitted across the thickness of the chip, or in some other direction?
A25. As stated on page 9, "the on-chip temperature variation, T_{max}-T_{min}, will not exceed 10 K". Re-stated, this means that the surface of the chip will have a T_{max}-T_{min} that is less than 10 K. Also, remember as stated on page 8, "It is expected that the choice of microchanneled and/or microgap cooling will be informed by the goal of providing a minimum 1 kW/cm^2 heat flux and 1 kW/cm^3 heat density removal without exceeding commonly accepted process and device operating temperature limits".

Q26. For the temperature rise of hot spot < 5 K metric, does this mean temperature rise over the average chip temperature, chip temperature at coolant inlet location, or some other location?
A26. As stated on page 10, "Proposals should describe the plan for hot spot mitigation. Details include how the 200 μm × 200 μm, 5 kW/cm^2 hot spot will be generated at the center of the chip surface and the specific thermal interconnects, vias, on-chip thermoelectric coolers, and/or other measures will be used to limit the hot spot temperature rise – above the uniformly heated maximum chip temperature – to 5 K". Re-stated, this means that with the added hot spot the temperature must not rise more than 5 K above the maximum chip temperature associated with uniform heating only.