SOL ENGINEERING SERVICES

CF-JET Stakeholder Guide

The key stakeholders in the CF-JET project, with a targeted guide and frequently asked questions for each role

Prepared for DEVCOM ARL program managers, GVSC engineers, university co-investigators, industry partners and the staff who support them

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Summary

This guide names the people and organizations with a stake in the CF-JET project and gives each role a guide written in the terms that role uses to make decisions. CF-JET is SOL Engineering Services' proposed cold plate for silicon carbide power electronics in Army vehicles, offered in response to solicitation ARL-BAA-0107. It combines a 3D printed jet-impingement body with interleaved return ports, a carbon fiber target plate with perpendicular pitch fiber inserts, and a thin electroplated coolant face.

The guide identifies eight roles: the Army Research Laboratory program manager, the vehicle engineers at the Ground Vehicle Systems Center, university co-investigators, research security and contracts staff, SOL's principal investigator and engineers, industry partners, the test and validation laboratory manager, and the transition stakeholders who would qualify, buy or fund a product. Table 1 lists each role with its stake and its primary decision. The roles come from the content of the research. No stakeholder agreement exists, the organizations named in this guide are examples cited in the research, and none has confirmed participation.

Four facts apply to every role. The design point is 1.5 kW on a 60 by 60 mm area, which is 41.7 W/cm² (computed), cooled by 50/50 water-glycol entering at 65 °C at 4 to 8 L/min, with a pressure drop of 30 kPa or less and a thermal resistance of 0.02 K/W. That target equals 72 mm²·K/W, inside the published range of 9 to 158 mm²·K/W, and no measurement of a printed jet array with interleaved returns near this size was found. The test definition matters as much as the hardware, because the case-temperature definition alone shifted measured resistance by 3.3 to 42.9 percent in a published study. Public Army documents give power density and coolant temperature targets and contain no module-level heat flux, resistance, flow or pressure drop requirement, so the design point is an assumption of the proposal.

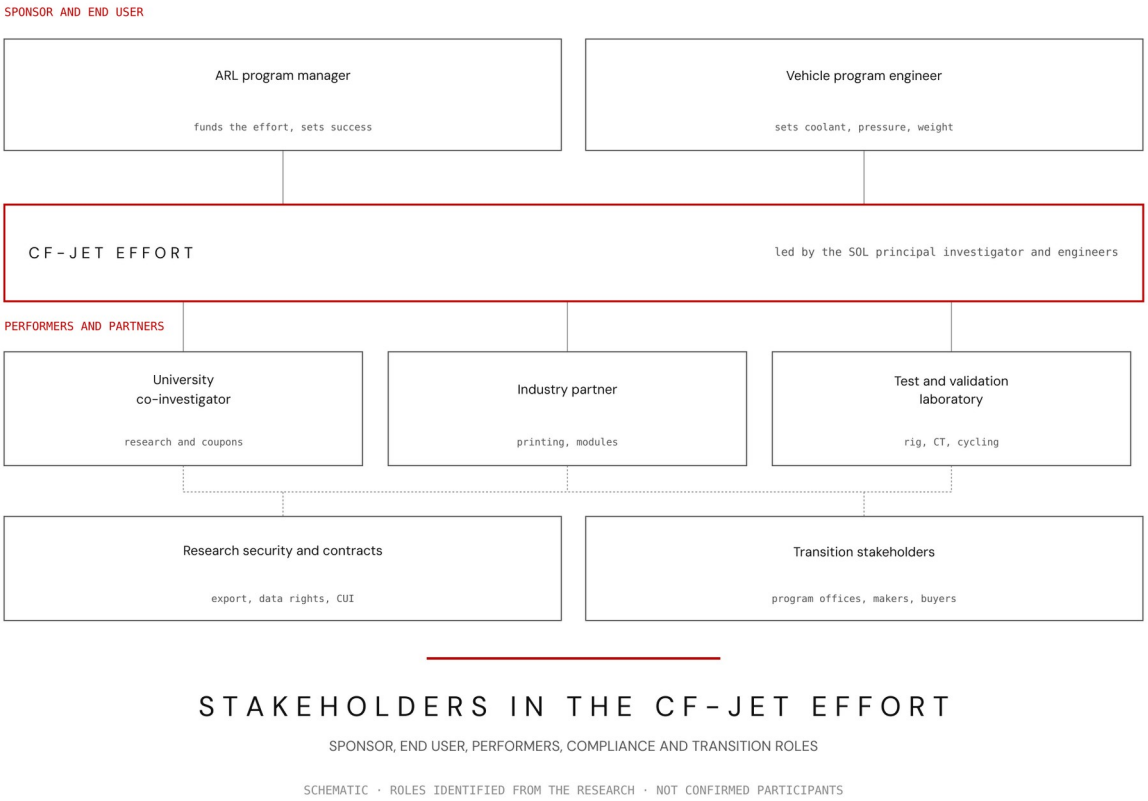
Each guide has four parts: what the project means for the role, the decisions the role makes with the evidence behind them, what to ask the team for, and answers to the questions that role is most likely to raise. Values marked computed were calculated for the research from cited inputs. Items marked gap were not found in the sources retrieved.

1. Who Has a Stake in CF-JET

1.1 Eight roles share the work and the decisions

The roles fall into four groups, shown in Figure 1. The sponsor and the end user set the requirement and the funding. SOL leads the effort, and university, industry and test partners perform parts of the work. Compliance staff control what the performers may share, publish and deliver. Transition stakeholders decide whether a validated plate becomes a product.

Figure 1. Stakeholders in the CF-JET effort



Schematic. Organizations are examples named in the research. Roles were identified from the research and are not confirmed participants.

Table 1. Stakeholder map

Role	Organization examples	Stake	Primary decision	Evidence
ARL program manager	DEVCOM Army Research Laboratory; topic point of contact for ARL-BAA-0107	Return on a funded research effort and milestones that can be tested	Whether to fund the effort and which results count as success	Solicitation ARL-BAA-0107; Army funding documents
Vehicle program engineer	DEVCOM Ground Vehicle Systems Center; Army vehicle program offices	A cooler that fits the vehicle coolant loop, weight and power budget	Whether the cooler meets thermal limits at the coolant the vehicle supplies	Public Army briefings and published studies
University co-investigator	HBCU and minority-serving institution faculty; Auburn University (CT); Alabama A&M, Tuskegee and Jackson State (printing and materials)	Research tasks, student training, publication and facility use	Which measurements the laboratory can commit to and publish	Capacity survey in the research; gaps stated
Research security and contracts staff	University sponsored-programs and research-security offices; SOL contracts and export-control staff	Compliance with export, data rights and CUI rules	Whether the work is fundamental research and whether CUI controls apply	Regulations and agency guidance; gaps stated
SOL principal investigator and engineers	SOL Engineering Services thermal and AI engineers	A defensible result at the design point	Which test comes first and how much margin the design includes	Peer-reviewed measurements and computed benchmarks

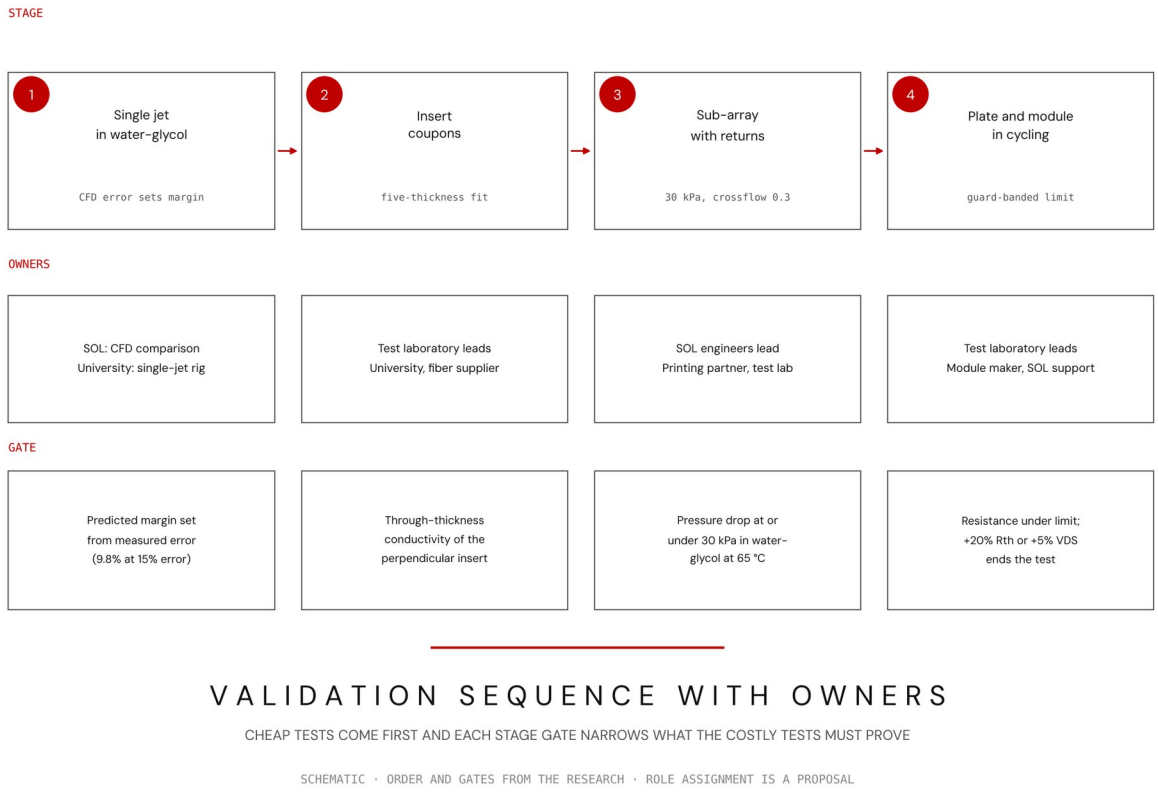
Role	Organization examples	Stake	Primary decision	Evidence
Industry partner	Additive manufacturing providers; power-module makers	Printable geometry, qualified modules and protected baselines	Whether to commit printing or module capacity to the effort	Peer-reviewed measurements; vendor claims unverified
Test and validation laboratory manager	University or contract facility with flow loop, laser flash, CT and thermal cycling capability	Measurements with a stated uncertainty	Which test definition, rig and acceptance limit to use	Standards and published rig studies; uncertainty computed
Transition stakeholders	Army program offices; vehicle and radar manufacturers; data center buyers; nonprofit intermediaries	A qualified product with a supply route	Whether to fund, qualify or buy a validated plate	Analyst estimates, trade reports and funding documents

Organizations are examples cited in the research as holding capacity or authority. None has confirmed participation in the effort.

1.2 The validation sequence assigns owners

The research recommends sequencing tests by cost, so that cheap tests narrow what the costly tests must prove. Figure 2 arranges the recommended tests as four stages and names the role that leads each stage and the result that gates it. Table 2 lists the part each role plays in each stage. The assignment of roles is a proposal assembled from the recommendations in the research and has not been agreed with any organization.

Figure 2. **Validation sequence with role owners**



Schematic. Stage order and gates follow the recommendations in the research. Role assignments are a proposal.

Table 2. **Role responsibilities by validation stage**

Role	Single jet	Insert coupons	Sub-array	Plate and module	Evidence
ARL program manager	Informed	Informed	Reviews	Reviews and accepts	Guard-banded acceptance limit in the testing and validation research
Vehicle program engineer	Informed	Informed	Supplies conditions	Reviews at 65 to 115 °C	Inlet temperatures of 65, 85, 105 and 115 °C in the Army electronics research
University co-investigator	Leads the rig	Supports	Informed	Supports	Single-jet rig as a teaching project; capacity survey
Research security and contracts staff	Reviews	Reviews	Reviews	Reviews	Export, data rights and CUI rules in the compliance research
SOL principal investigator and engineers	Leads the CFD comparison	Supports	Leads	Supports	Validate the simulation first; test a sub-array with returns
Industry partner	Informed	Supports	Supports	Supports	Build rules from the printing research; controlled module pairs
Test and validation laboratory manager	Supports	Leads	Supports	Leads	Test definition and uncertainty in the testing research
Transition stakeholders	Informed	Informed	Informed	Reviews results	Component-level budgets and qualification by a prime in the market research

Assignments are proposed here from the recommendations in the research and are not agreed with any organization.

1.3 One design point serves every role

Every role works from the design point in Table 3. The values are assumptions of the proposal or values computed from them, and no Army document states them as requirements.

Table 3. CF-JET design point and what it means

Quantity	Value	Meaning for the roles	Evidence
Heat load	1.5 kW	Within the 2 to 12 kW that one conversion stage gives off	Design assumption of the proposal
Cooled area	60 mm by 60 mm (36 cm^2)	The footprint of one module position	Design assumption of the proposal
Average heat flux	41.7 W/cm^2	Die-level flux is 12 to 24 times this footprint value	Computed from 1,500 W over 36 cm^2
Coolant	50/50 water-glycol, 65 °C inlet	The current Army inlet temperature in public documents; the future range is 80 to 105 °C	Design assumption; Army range from public documents
Flow rate	4 to 8 L/min	Sets a coolant rise of 3 to 6 K	Design assumption; rise from the testing research
Pressure drop	30 kPa or less	Most of a 34.5 kPa loop budget that other components share	Design assumption; loop budget from Army documents
Thermal resistance	0.02 K/W, or 72 mm^2·K/W	The acceptance target	Computed from 0.02 K/W times 3,600 mm^2
Temperature rise at full load	30 K, giving a 95 °C case at a 65 °C inlet	Exceeds the 80 °C limit stated for radar transmit and receive modules	Computed from 1,500 W times 0.02 K/W

1.4 Each role asks a different first question

Table 4 lists the question each role asks first, the number that answers it and the study in the research that holds the detail. The number is the figure a role should expect to see first in a briefing.

Table 4. First question and first number for each role

Role	First question	Number that answers it	Evidence
ARL program manager	Is the target credible?	72 mm^2·K/W against 9 to 158 published and 100 to 200 for conventional plates	Limits of Conventional Liquid Cold Plates and Jet-Impingement Crossflow; interpretation of published data
Vehicle program engineer	Does it work at vehicle coolant temperatures?	A design validated at 65 °C loses 36 to 58 percent of module capacity at 105 °C	Thermal Management Demands of Silicon Carbide Power Electronics in Army Ground Vehicles; computed
University co-investigator	What can our laboratory measure?	No flow loop, laser flash or thermal cycling documented at an HBCU or community college	Test Infrastructure, Validation, and Quality Assurance for AM Thermal Hardware; gap stated
Research security and contracts staff	Which rules apply?	110 CUI requirements; 20 years of SBIR data protection	Program, Teaming, Data Rights, and Compliance Considerations; regulations
SOL principal investigator and engineers	What error does the design include?	A 9.8 percent margin at a 15 percent model error	Engineering Design Under Sparse Data; computed
Industry partner	Can the plate be printed and qualified?	A horizontal 1 mm channel printed at 805 µm, which raises pressure drop 2.4 times	Additively Manufactured Jet-Impingement Cold Plates with Interleaved Returns; measured and computed

Role	First question	Number that answers it	Evidence
Test and validation laboratory manager	Can the rig verify 0.02 K/W?	±10.6 percent reported on 0.0198 K/W	Test Infrastructure, Validation, and Quality Assurance for AM Thermal Hardware; reported
Transition stakeholders	How large is the market and who buys?	Estimates of $0.87 to $4.97 billion for 2024	Markets, Transition Pathways, and Commercialization for Advanced Cold Plates; analyst estimates

2. Guide for the ARL Program Manager

2.1 A credible target with unproven hardware

The program manager decides whether the effort deserves funding and which result counts as success. The project asks for research support for a cooler that must remove 1.5 kW from a 36 cm² area at a pressure drop of 30 kPa or less, using coolant at 65 °C. The research gives three reasons to take the target seriously. The target of 72 mm²·K/W lies inside the published range of 9 to 158 mm²·K/W and well under the 100 to 200 mm²·K/W of conventional finned and swaged-tube plates. A printed cooler measured at 21 to 35 mm²·K/W on 1 cm² shows that printing can reach the range. Modeling favors aluminum silicon carbide over copper and aluminum by 11 to 22 times in strain energy, and one test showed at least 18 times the life.

The research also gives several reasons to ask for staged proof. The CF-JET plate is 36 times the area of the best printed cooler measured. No measurement exists for a printed jet array with interleaved returns near this size, or for a millimeter-thick carbon fiber insert at 6 to 9 percent fiber. No published life test varies only the cold plate expansion in a silicon carbide module. Public Army documents give power density targets of 3 kW/L today and 12 kW/L in future, and coolant temperatures of 65 °C today and 80 to 105 °C in future, with no module-level requirement. The program manager can close that gap by asking the Ground Vehicle Systems Center for component-level thermal budgets before the effort sizes a demonstration.

In the validation sequence of Figure 2, the program manager reviews the sub-array result and accepts the plate and module result against the guard-banded limit. The first two stages inform the manager and need no decision. The most useful review points are the single-jet error, which sets the margin, and the sub-array pressure drop, which shows whether the 30 kPa budget is achievable.

2.2 Decisions and the evidence behind them

Table 5. Decisions for the ARL program manager

Decision	What the research shows	What is unproven	Evidence
Accept 0.02 K/W as the success target	The target equals 72 mm²·K/W, inside the published range of 9 to 158 mm²·K/W	No measurement of a printed jet array with interleaved returns near this size	Interpretation of published data; gap stated
Set the acceptance limit	Instruments verify resistance to about ±3.0 percent. A published rig reported ±10.6 percent on 0.0198 K/W. Guard-banded limits are 0.0194 K/W at instrument level and 0.0179 K/W at university-rig level	The uncertainty that the program rig will reach	Standards and published rig studies; limits computed

Decision	What the research shows	What is unproven	Evidence
Tie success to an Army requirement	Public documents give power density and coolant temperature targets	No module-level heat flux, resistance, flow or pressure drop requirement	Government documents; gap stated
Choose a funding route that reaches the performers	HBCU and minority-institution vehicles fund institutions only. A 2026 pilot closed with applications due 10 April 2026	Whether BAA-funded work can feed an SBIR Phase III award	Government solicitations; gap stated

2.3 What to ask the team for

- A test plan that names the case-temperature definition, the interface material, the joining pressure and the inlet temperature in the statement of 0.02 K/W, because these choices alone move the result by 3.3 to 42.9 percent.
- A guard-banded acceptance limit, with the uncertainty reported alongside every result.
- A stated result at each of the four test stages that ends the stage or allows the work to continue.
- Resistance reported at the 65 °C design inlet and at the 45 °C reference fluid of the industry specification, so that results can be compared with vendor claims.
- A predicted margin set from the error budget: 9.8 percent at a 15 percent model error and 17.3 percent at a 30 percent error.

2.4 Frequently asked questions

How aggressive is the target? The target of 72 $mm^2 \cdot K/W$ lies inside the published range for jet and microchannel coolers and well under the range for conventional plates. The scale is the larger concern: the target applies to 36 cm^2, and the best printed cooler measured reached 21 to 35 $mm^2 \cdot K/W$ on 1 cm^2.

What would the first test tell the program? The research recommends a single-jet test at the CF-JET jet diameter in water-glycol before any other test. It measures the error of the simulation at application conditions. Published comparisons in air gave area-averaged medians under 10 percent and maxima near 15 percent, while a 2025 round-nozzle validation reported a 24.7 percent average and 39.3 percent local error. No comparison exists for water-glycol at the CF-JET jet size.

Will the AI methods reduce the number of prototypes? Published surrogate models match simulations within 0.2 to 2 percent after 20 to 100 simulations, and a hybrid model reached 3.1 percent error outside its training region against 7.0, 15.1 and 15.7 percent for other methods on a synthetic problem. No study covers a jet array of 100 to 150 jets with interleaved returns and a composite plate, so the effect on prototype count is a hypothesis for the program to test. For scale, a National Renewable Energy Laboratory program spent $1.6 million over fiscal years 2011 to 2013 on three prototypes, while nine variables at three levels give 19,683 combinations, which is 6,561 times as many (computed).

Can BAA-funded research lead to an SBIR Phase III award? No retrieved source shows that it can. Phase III and the Strategic Breakthrough Award both depend on prior SBIR work, a prior Phase II or a matched program commitment. The question is open, and Army topics that fit the CF-JET plate are the first thing to identify.

What does the effort need from the Army? Component-level thermal budgets for vehicle power electronics and directed energy systems, including the heat load by component and the coolant temperature at each. The research recommends obtaining them from GVSC and C5ISR programs before sizing a demonstration.

3. Guide for the Vehicle Program Engineer

3.1 Inlet temperature and loop pressure decide fit

Vehicle engineers decide whether a cooler meets thermal limits at the coolant temperature and pressure that the vehicle supplies. Hybrid combat vehicles convert 100 to 400 kW of electrical power, and at losses of 2.15 to 3 percent one conversion stage gives off 2 to 12 kW of heat. A stage at 12 kW is eight times the 1.5 kW design point (computed), so a full stage may need several plates or a larger plate, and the research recommends testing serial and parallel arrangements. The power density target rises from 3 kW/L today to 12 kW/L in future.

Inlet temperature is the largest uncertainty. Public Army documents give 65 °C as the current electronics inlet, and a 2019 GVSC briefing lists 85 °C as the current reference and 105 °C as the future requirement. A design validated at 65 °C loses 36 to 58 percent of its module capacity at 105 °C if its resistance is unchanged. The loop offers 2 to 5 psi (14 to 34 kPa) of pressure drop to electronics, and a 30 kPa cold plate uses most of it. Connecting three modules one after another at 4 L/min raises the inlet temperature of the third module by about 12 K. The research found no published XM30 inlet temperature.

Table 2 gives the vehicle engineer two parts: supplying the coolant conditions for the sub-array tests and reviewing the module results at inlet temperatures from 65 to 115 °C. The most useful contribution is a stated inlet temperature, pressure budget and flow for the test, because the research found none at module level in public documents.

3.2 Decisions and the evidence behind them

Table 6. Decisions for the vehicle program engineer

Decision	What the research shows	What is unproven	Evidence
Coolant inlet temperature to design for	Public Army documents give 65 °C as the current inlet and 80 to 105 °C as the future range. A design validated at 65 °C loses 36 to 58 percent of module capacity at 105 °C	The XM30 inlet temperature; loop pressure at 115 °C; boiling at a 105 °C inlet	Army documents and published studies; gaps stated
Pressure the cooler may use	The loop offers 2 to 5 psi (14 to 34 kPa). The 30 kPa budget fits one module, and other components share the loop	The share of the 30 kPa that the manifold uses	Army documents; gap stated
Heat flux basis for comparing coolers	Die-level heat flux is 12 to 24 times the footprint value	The basis that a vehicle specification will use	Published studies; computed
Weight, volume and pump power	The research recommends reporting mass, coolant volume and pump power with every result	Plate mass against copper and AlSi10Mg; weight and volume that vehicle thermal systems may use	Gap stated

3.3 What to ask the team for

- Junction-to-coolant resistance at inlet temperatures of 65, 85, 105 and 115 °C.
- Pressure drop at each temperature, at both 4 and 8 L/min.
- Heat flux on a footprint basis and on a die basis, since die-level flux is 12 to 24 times the footprint value.
- Tests in serial and parallel arrangements, with the coolant rise and manifold pressure drop quoted

for three-module installations.

- Mass, coolant volume and pump power for each result.
- Results at engine-off, low-flow conditions.

3.4 Frequently asked questions

At what coolant temperature has the design been shown to work? The design point assumes 65 °C, and no measurement of the plate exists at any temperature. The research recommends resistance at 65, 85, 105 and 115 °C because capacity falls 36 to 58 percent when a design validated at 65 °C operates at 105 °C. Boiling at a 105 °C inlet is possible and has not been assessed.

Does the cooler fit the vehicle loop pressure? A 30 kPa budget fits within the 14 to 34 kPa loop for a single module, and several modules, motors and a battery share the same loop. Printed channels come out smaller than designed, and a 19.5 percent undersize gives 2.4 times the pressure drop (computed), so the printed jet size is the main pressure risk. Jets under about 0.56 to 0.6 mm exceed 30 kPa.

Will the plate survive thermal cycling? One aluminum silicon carbide plate cycled 1,800 times from −40 to 150 °C without failure. The AQG 324 qualification basis comes from automotive practice and contains no Army mission profile, so the research recommends cycles with swings of 75 to 125 °C and junction temperatures to 175 °C.

Does the plate help in engine-off operation? No result exists. The research recommends low-flow testing, because silent-watch operation changes the coolant conditions that the vehicle supplies.

What heat loads should the engineer supply for sizing? The open question is the heat load by component for vehicle microgrid power electronics and directed energy systems, and the coolant temperature that each receives. Component-level thermal budgets from GVSC and C5ISR programs would let the team size a demonstration to a vehicle need.

4. Guide for the University Co-Investigator

4.1 University measurements are useful and capacity has gaps

Co-investigators decide which measurements their laboratories can commit to and publish. The research identifies work that suits a university: single-jet validation, through-thickness conductivity of carbon fiber coupons, thermal expansion of the finished plate, micro-CT of printed and plated parts, and coupon builds. Capacity named in the research includes CT at Auburn University, additive manufacturing laboratories at Calhoun, Mississippi Gulf Coast and East Mississippi community colleges, and printing and materials work at Alabama A&M, Tuskegee and Jackson State. No retrieved source documents a flow loop, laser flash or thermal cycling at an HBCU or community college.

Funding rules decide who is paid. The HBCU and minority-institution vehicles retrieved fund institutions only. The 2026 pilot expects fundamental research, funds no equipment and bars subawards, and its applications closed on 10 April 2026. A university that holds an award can collaborate with SOL on research that the award funds, and any exchange of data or software then needs a written agreement that states what each party contributes.

In Figure 2 the co-investigator leads the single-jet rig and supports the coupon, sub-array and module stages. The rig is the cheapest measurement in the sequence, and its result sets the margin for every

simulation-based prediction that follows.

4.2 Decisions and the evidence behind them

Table 7. Decisions for the university co-investigator

Decision	What the research shows	What is unproven	Evidence
Which tests to commit to	A single-jet rig can be built as a teaching project, and Auburn University holds CT capacity	No flow loop, laser flash or thermal cycling is documented at an HBCU or community college	Capacity survey in the research; gap stated
How to measure conductivity through the plate	A regression on five thicknesses recovered conductivity where single-specimen readings gave 33 to 75 percent of the true value in a model	Conductivity of perpendicular pitch fiber inserts at several pitches; lateral diffusion in laser flash	Computed; gap stated
Which defects to look for by CT	A 30 µm voxel detects features of 90 µm; 5 µm scans of sub-regions find the pore population	Whether CT detects voids and delamination in the plated face and its bond to the body	Computed; gap stated
What to publish	Fundamental research rules protect the publication of basic research on campus	No source classifies a cold plate for export control	Regulations; gap stated

4.3 What to ask the team for

- A written statement of the tests the laboratory is asked to perform, with voxel size, flow rate and temperature for each.
- Coupons built like the plate, with the interface material and contact pressure recorded for each measurement.
- Measurement of thermal expansion on the finished plate from 25 to 175 °C.
- A scoping visit to confirm equipment, because the capacity survey found no documented flow loop.
- A written agreement on the ownership of baseline software and data before students begin work.

4.4 Frequently asked questions

Can faculty and students publish results? Fundamental research rules protect the publication of basic research performed on campus, and the research cites National Security Decision Directive 189 and the exclusion at 15 C.F.R. § 734.8, together with the public domain provision at ITAR 120.34. Physical items and work outside the campus are treated differently, and no source classifies a cold plate for export control. The sponsored-programs and research-security offices should confirm the status before the first publication.

What can a community college or HBCU laboratory contribute? Printing and materials work, coupon builds and, with a scoping visit, a single-jet rig. The research proposes the rig as a teaching project, which lets students build and operate a measurement that the first test stage needs.

Which research questions are open? The through-thickness conductivity of plates with perpendicular pitch fiber inserts at several pitches, and the best measurement method. Whether laser flash shows lateral diffusion that breaks the one-dimensional model. Whether micro-CT detects voids and delamination in the plated face and its bond. How many validation plates each region needs, given that 46 points separate 95

percent coverage from 85 percent coverage.

How are data rights decided? The contract vehicle decides. SBIR and STTR awards protect data for 20 years and then give the Government perpetual government purpose rights, and no source states proof-of-ownership requirements for software baselines.

5. Guide for Research Security and Contracts Staff

5.1 Several rules need determinations before work starts

These staff decide whether the work qualifies as fundamental research, whether controlled unclassified information (CUI) is involved, and who holds data rights. The research found no source that classifies a cold plate for export control, and none that describes proof-of-ownership requirements for software baselines. The AI portion of the toolkit also lacks a documented export status.

The rules are specific. National Security Decision Directive 189 separates research that is publishable from research that is restricted. DFARS 252.227-7017 requires data-rights assertions before award. DFARS 252.204-7012 applies NIST SP 800-171 Revision 2 to systems that handle CUI, which means 110 requirements in 14 families and incident reporting within 72 hours. The Cybersecurity Maturity Model Certification schedule moved during 2026, so the status at the time of award needs checking.

Table 2 marks these staff as reviewers at every stage, because each stage produces data that moves between a laboratory, a partner or a publication. The review is a check on what moves and under which rule.

5.2 Decisions and the evidence behind them

Table 8. Decisions for research security and contracts staff

Decision	What the research shows	What is unproven	Evidence
Treat the work as fundamental research	EAR 734.8 covers fundamental research and ITAR 120.34 covers public domain information. The 2026 pilot expects fundamental research	No source classifies a cold plate or the AI portion of the toolkit for export control	Regulations; gap stated
Assert data rights	SBIR and STTR data are protected for 20 years and then fall under perpetual government purpose rights. DFARS 252.227-7017 requires assertions	Proof-of-ownership requirements for software baselines	Regulations; gap stated
Apply CUI controls	DFARS 252.204-7012 requires NIST SP 800-171 Revision 2: 110 requirements in 14 families, with incident reporting in 72 hours	Whether the work will generate CUI	Regulations
Plan for CMMC	Phase 1 began on 10 November 2025. Phase 2 was scheduled for 10 November 2026 and the Government suspended it on 13 July 2026	The current status of Phase 2 at the time of award	Government notices and trade reports; verify before award
Choose a vehicle that pays the right party	The retrieved HBCU and minority-institution vehicles fund institutions only. The 2026 pilot bars subawards and equipment	The terms that a nonprofit intermediary would apply	Government solicitations; gap stated

5.3 What to ask the team for

- A statement of what each party contributes and where results will be published.

- Data-rights assertions for each deliverable, with the baseline models and software listed before work starts.
- A CUI incident plan that meets the 72-hour reporting requirement.
- A university agreement that states the terms for data, background software and student access.
- A determination of export status for the AI portion of the toolkit.

5.4 Frequently asked questions

Is the work fundamental research? Basic research performed on campus can qualify, and the 2026 pilot states that the Government expects fundamental research. The cold plate hardware and the AI toolkit have no documented classification, so the offices should determine the status of each deliverable before publication plans are made.

Does CUI apply, and what does it require? If the work generates or receives CUI, DFARS 252.204-7012 applies with NIST SP 800-171 Revision 2. That standard has 110 requirements in 14 families, and incidents must be reported within 72 hours. The research recommends an incident plan before work starts.

Who owns the baseline models and software? The research found no source that states proof-of-ownership requirements for software baselines. The practical safeguard is to list each baseline before award and assert rights under DFARS 252.227-7017.

How long are data protected after an SBIR or STTR award? For 20 years, after which the Government holds perpetual government purpose rights.

Is CMMC in effect for this award? Phase 1 began on 10 November 2025, and Phase 2 was scheduled for 10 November 2026. The Government suspended Phase 2 on 13 July 2026, and program offices may require a lower level. The status should be confirmed against the solicitation at the time of award.

6. Guide for SOL's Principal Investigator and Engineers

6.1 Validate the simulation before trusting the surrogate

SOL's engineers decide which test comes first and how much margin the design includes. The research recommends validating the simulation first. A surrogate model trained on simulation results reproduces the simulation error, which ranged from 1.6 to 39 percent depending on the closure and the quantity compared, and only measurements correct it. A single-jet measurement at the CF-JET diameter in the working fluid is the cheapest test that bounds the error. The predicted margin that results is 9.8 percent at a 15 percent error and 17.3 percent at a 30 percent error.

Design rules from the printing and carbon fiber research apply from the first drawing. Orient orifices along the build direction, keep jets over about 0.6 mm until nozzles are sized from measured CT data, add drain and access ports, and avoid bends. The process limits to enter in the optimization are a wall of about 0.3 mm and a fin of about 150 µm. The resistance budget is tight: a 1 mm insert at 36 W/m·K uses 28 of the 72 mm^2·K/W budget, a 2 mm insert uses 55, and a 50 µm plastic skin uses 172, which exceeds the whole budget. The plated face of 10 to 25 µm must be the sealed face.

The AI toolkit that SOL proposes depends on calibrated uncertainty. A Gaussian process on a synthetic five-input problem placed 98.6 percent of points within ±5 percent at 200 training points, and its intervals covered 95.8 to 99.1 percent of points. Ensembles of five networks covered only 52.8 to 75.1 percent at a

nominal 95 percent. An optimizer that searches for the best predicted design finds the points where such intervals fail. All benchmark values come from synthetic problems, so they test the software and say nothing about CF-JET hardware.

Figure 2 gives SOL the CFD comparison in the first stage and the lead in the sub-array stage, with a supporting part in the coupon and module stages. The sub-array is the stage where printed geometry, pressure drop and the AI toolkit meet, and the research recommends testing it with and without returns.

6.2 Decisions and the evidence behind them

Table 9. Decisions for SOL's principal investigator and engineers

Decision	What the research shows	What is unproven	Evidence
Test the simulation first	Area-averaged medians under 10 percent and maxima near 15 percent in air; 24.7 percent average and 39.3 percent local in a 2025 round-nozzle validation	No comparison in water-glycol at the CF-JET jet size	Peer-reviewed measurements; gap stated
Size the jets	Jets under about 0.56 to 0.6 mm exceed 30 kPa. A horizontal 1 mm channel printed at 805 µm	As-built nozzle size at 25 to 36 times the scale of printed precedents	Peer-reviewed measurement; computed
Specify the insert	Perpendicular fiber at 6 to 9 percent is needed for 50 W/m·K. Printed pitch fiber reached 36.63 W/m·K at 6.42 percent	Conductivity of a 1 to 2 mm insert; fiber breakage in printing at 0.4 percent failure strain	Peer-reviewed and vendor data; gap stated
Trust the surrogate to select designs	Gaussian process intervals covered 95.8 to 99.1 percent of points; ensembles of five covered 52.8 to 75.1 percent	Coverage on held-out CF-JET designs and measured points	Computed benchmark on a synthetic problem; gap stated

6.3 What to ask the team for

- Area-averaged and stagnation heat transfer reported separately, with the comparison error stated alongside the ASME V&V 20 validation uncertainty.
- A defined case reference plane, and a crossflow ratio kept at about 0.3 or lower.
- A pressure budget split by component: manifold, returns and jets.
- A representative sub-array tested with and without returns in water-glycol at 65 °C and 4 to 8 L/min.
- Ten to 20 paired designs at two mesh levels before a ladder of model tiers is adopted.
- Each surrogate prediction labeled as interpolation or extrapolation.
- About 13 replicates at each setting, which give a relative standard error of 20 percent in the estimated deviation (derived from normal theory).
- Every new hardware batch scored against the current model before it joins the training set.
- A release record that logs the solver version, mesh, closure, inputs and results for every simulation, and names the engineer who accepted each release.

6.4 Frequently asked questions

Which test comes first? The single-jet comparison against the simulation, in water-glycol at the CF-JET jet size. It is the cheapest test and it sets the margin that every simulation-based prediction needs.

How much margin should the design include? The research sets the predicted margin at 10 percent or

more for the conduction shares it assumed. The computed values are 9.8 percent at a 15 percent error and 17.3 percent at a 30 percent error, and a root-sum-square of a 5 percent surrogate error and a 15 percent simulation error gives 15.8 percent.

Can the surrogate be trusted to select designs? Only after its intervals are checked. No cooler study reports interval coverage, ensembles covered 52.8 to 75.1 percent in the benchmark, and a hybrid model covered 70.9 percent in a far region at 60 training points against a nominal 95 percent. The research recommends a Gaussian process for scalar outputs, coverage tests on held-out points and recalibration before the surrogate selects a design.

What interval width is acceptable? The engineers set the criterion from the margin the budget leaves. A 10 percent interval on 0.02 K/W is 0.002 K/W, which equals 3 K of case-to-coolant rise at 1.5 kW (derived).

What should the first insert and skin use? The research recommends a high-modulus fiber near 800 W/m·K with the tow conductivity measured, a sliced or pin-based insert for the 300 W/m·K case, and PEEK for the first builds. Jets should stay under 1 mm and the plated face should be tested at the intended velocity, because plating adhesion in hot glycol is unmeasured and pitch fiber breaks in printing at a 0.4 percent failure strain.

How many validation points are needed? About 46 points separate 95 percent coverage from 85 percent coverage. Counts should be reported with intervals, batches pooled by region and measurements replicated.

7. Guide for Industry Partners

7.1 Scale and module pairing are the industry risks

Industry partners decide whether to commit printing or module capacity. Printing providers face the scale of the plate: it is 36 times the area of the best printed cooler measured, and 25 to 36 times larger than printed precedents. Channels come out smaller than designed, since a 1 mm channel printed at 988 µm and a horizontal channel at 805 µm. Powder entrapment and material property variation of 18 to 41 percent with annealing add to the risk.

Power-module makers face a pairing problem. Copper expands at 16.5 to 17 ppm/K, aluminum at 22.2 to 25 and silicon carbide at 3.4 to 4, and the strain energy of aluminum silicon carbide is 0.18 MPa against 1.94 for copper and 3.93 for aluminum. The ceramic and the plate must be chosen as a pair. A nickel-phosphorus coating cracked within 1,000 cycles in an analog case, so the plated face of the CF-JET plate needs its own cycling evidence.

Table 2 assigns industry partners a supporting part in the coupon, sub-array and module stages. A printing partner supplies the sub-arrays and coupons, and a module maker supplies the controlled pairs for the final stage.

7.2 Decisions and the evidence behind them

Table 10. Decisions for industry partners

Decision	What the research shows	What is unproven	Evidence
Printing orientation and geometry	Orient orifices along the build direction, add drain and access ports and avoid bends. Process limits are a wall of about 0.3 mm and a fin of about 150 µm	Powder removal at the CF-JET scale	Peer-reviewed measurements; gap stated
Pressure budget	A 19.5 percent undersize gives 2.4 times the pressure drop	As-built nozzle diameters from CT data	Computed
Module pairing	Aluminum silicon carbide strain energy is 0.18 MPa against 1.94 MPa for copper and 3.93 MPa for aluminum. One plate cycled 1,800 times from −40 to 150 °C without failure	No published life test varies only the cold plate expansion in a silicon carbide module	Peer-reviewed modeling and one test; gap stated
Protection of baselines	DFARS 252.227-7017 requires assertions, and SBIR data are protected for 20 years	Proof-of-ownership requirements for software baselines	Regulations; gap stated
Market position	Vendors claim 4,000 W single-phase and 4,500 W two-phase cooling, and large infrastructure groups are absorbing cold plate suppliers	Independent test results for the vendor claims	Trade reports and vendor data; unverified

7.3 What to ask the team for

- Controlled module pairs that differ only in the cooled base: copper, aluminum silicon carbide and CF-JET.
- Cycles with swings of 75 to 125 °C and junction temperatures to 175 °C, with resistance monitored every cycle.
- Both failure criteria reported: a 5 percent rise in drain-source voltage and a 20 percent rise in thermal resistance.
- A statement of model conditions with every lifetime estimate.
- A family of plate areas: 55 cm^2 at 41.7 W/cm^2 handles 2,300 W (computed), so a family would cover 700 to 2,300 W.

7.4 Frequently asked questions

Can the plate be printed at this size? The research does not demonstrate it. The best printed cooler measured reached 21 to 35 $mm^2 \cdot K/W$ on 1 cm^2, and CF-JET needs 36 times that area. A representative sub-array tested with and without returns is the recommended proof.

How do printed channels differ from the drawing? A 1 mm channel printed at 988 µm and a horizontal channel at 805 µm. The 19.5 percent undersize of the horizontal case gives 2.4 times the pressure drop (computed), so nozzle sizes should come from measured CT data.

What property variation should a supplier expect? Material properties varied by 18 to 41 percent with annealing in the research reviewed, so builds should be qualified by measuring the finished plate.

What must a module maker test? Controlled pairs of modules that differ only in the cooled base, cycled with swings of 75 to 125 °C, with both failure criteria reported and resistance monitored every cycle. The research found no published test that varies only the cold plate expansion.

How are our baselines protected? Through data-rights assertions under DFARS 252.227-7017, made before award, and through 20 years of SBIR data protection. No source states proof-of-ownership requirements for software baselines.

How do vendor claims compare? Vendors claim 4,000 W single-phase and 4,500 W two-phase cooling, and no independent test supports either claim. Cold plate suppliers are also being absorbed by large infrastructure groups, which control channels to the largest customers.

8. Guide for the Test and Validation Laboratory Manager

8.1 The test definition decides the result

Laboratory managers decide the test definition, the rig and the acceptance limit. The research finds that the definition matters more than the instruments. Instrument terms give ±3.0 percent, while the case-temperature definition changed resistance by 3.3 to 42.9 percent and joining pressure by 34.2 percent. A published rig reported ±10.6 percent on 0.0198 K/W, so an acceptance of 0.02 K/W falls inside that rig uncertainty.

Standards leave gaps. ASTM E1461 and D5470 do not address oriented inserts, and contact resistance biased a single specimen low by 33 to 75 percent in a model. A full-plate CT scan at a 30 µm voxel detects features of 90 µm, so smaller defects escape it. The specification reference temperature of 45 °C differs from the 65 °C design inlet.

Figure 2 gives the laboratory the lead in the coupon stage and in the plate and module stage, the two stages where the measurement definition and its uncertainty decide the result. The laboratory supports the single-jet and sub-array stages.

8.2 Decisions and the evidence behind them

Table 11. Decisions for the test and validation laboratory manager

Decision	What the research shows	What is unproven	Evidence
Test definition	The case-temperature definition shifted resistance by 3.3 to 42.9 percent, and joining pressure by 34.2 percent	The definition that reproduces the CF-JET heat path with the smallest uncertainty	Peer-reviewed study; gap stated
Acceptance limit	The limit equals the requirement less the expanded uncertainty: 0.0194 K/W at instrument level and 0.0179 K/W at university-rig level	The uncertainty of the program rig	Computed
Conductivity method	ASTM E1461 and D5470 do not address oriented inserts, and contact resistance biased a single specimen low by 33 to 75 percent	The method with the smallest uncertainty; lateral diffusion in laser flash	Standards and computed; gap stated
Defect inspection	A 30 µm voxel detects features of 90 µm, and 5 µm sub-region scans find the pore population	CT of the plated face and its bond	Computed; gap stated
Sample size	46 points separate 95 percent coverage from 85 percent coverage	Plates per region when measurement noise is half the prediction deviation	Computed; gap stated

8.3 What to ask the team for

- The case-temperature definition, interface material, joining pressure and inlet temperature written into the requirement.

- A rig calibrated with a reference plate, and the uncertainty stated with each result.
- A matched inlet and outlet temperature pair near ±0.05 K, because the coolant rise is 3 to 6 K at 4 to 8 L/min.
- Resistance tests at the 65 °C design inlet, with fluid properties and set point recorded for each test.
- Coupons measured at five thicknesses, with interface material and contact pressure recorded.
- Counts reported with intervals, batches pooled by region and measurements replicated.
- Resistance monitored at every cycle in thermal cycling.

8.4 Frequently asked questions

Can the rig verify 0.02 K/W? At instrument-only uncertainty of ±3.0 percent the guard-banded limit is 0.0194 K/W, and at the ±10.6 percent level of a published university rig it is 0.0179 K/W (computed). A rig that cannot reach the first level needs a reference plate for calibration.

Which temperature definition should the test use? The definition has to be written into the test plan, and the open question is which definition and interface reproduce the CF-JET heat path in a thermal test vehicle with the smallest uncertainty.

How is conductivity through the plate measured? With multi-thickness coupons and a controlled interface. A regression on five thicknesses recovered the conductivity in a model where single-specimen readings gave 33 to 75 percent of the true value. A lateral diffusion check is needed with laser flash.

Which CT voxel size should be used? The one that matches the feature of interest. Full-plate scans at 30 µm find large voids, and 5 µm scans of sub-regions find the pore population. Thresholds are calibrated on a known specimen.

How many validation points are needed? About 46 points separate 95 percent coverage from 85 percent coverage, and more are needed when measurement noise is large.

Which facilities are available? Auburn University holds CT capacity. No retrieved source documents a flow loop, laser flash or thermal cycling at an HBCU or community college, so the research recommends scoping visits and building a single-jet rig as a teaching project.

9. Guide for Transition and Commercialization Stakeholders

9.1 Market estimates and operating limits vary widely

These stakeholders decide whether to fund, qualify or buy a validated plate. The market evidence is uncertain: estimates of the 2024 data center liquid cooling market range from $0.87 to $4.97 billion, a 5.7-fold spread that depends on scope. Accelerator power rose from 700 W in 2022 to 2,300 W in 2026, with over 4,000 W projected for 2029. At 0.02 K/W, 2,300 W gives a 46 K rise (computed) against 30 K at the design point, so a family of plate areas is needed. A plate of 55 cm² at 41.7 W/cm² handles 2,300 W (computed).

Radar needs a lower inlet. The design point gives a 95 °C case at full load, over the 80 °C limit stated for active electronically scanned array transmit and receive modules. A 50 °C inlet meets the 80 °C limit at 1.5 kW before module-to-case resistance is counted (computed). Funding ceilings range from $167,500 to $30 million, and Phase III and the Strategic Breakthrough Award depend on prior SBIR work, a prior Phase II or

a matched program commitment.

Table 2 lists transition stakeholders as informed in the first three stages and as reviewers of the module results. The research recommends that they supply component-level thermal budgets before a demonstration is sized, which places their input before the sub-array stage.

9.2 Decisions and the evidence behind them

Table 12. Decisions for transition and commercialization stakeholders

Decision	What the research shows	What is unproven	Evidence
Size the opportunity	Estimates of the 2024 data center liquid cooling market range from $0.87 to $4.97 billion	Which scope applies to an Army-derived plate	Analyst estimates
Choose a funding route	Ceilings range from $167,500 to $30 million. The SBA Phase II guideline is $2.24 million and CATALYST offers up to $15 million	Whether BAA-funded work qualifies for SBIR Phase III or the Strategic Breakthrough Award	Government solicitations; gap stated
Match the plate to radar	The design point gives a 95 °C case at full load, over the 80 °C limit for transmit and receive modules. A 50 °C inlet meets the limit at 1.5 kW before module-to-case resistance	Radar heat loads and module-to-case resistance	Computed; gap stated
Benchmark against vendors	Vendors claim 4,000 W single-phase and 4,500 W two-phase cooling	Independent tests of the claims	Vendor claims; unverified
License the AI toolkit	No retrieved source gives prices for AI toolkit licensing	Prices under unit, token and subscription models	Gap stated

9.3 What to ask the team for

- Resistance reported as (Ts − Tl)/P with six or more flow rates, at the 65 °C design inlet and at the 45 °C reference fluid of the industry specification.
- A plate-area family that covers 700 to 2,300 W.
- A lower-inlet configuration for radar.
- A Phase II-type structure like the one Advanced Cooling Technologies used: a named prime, prototypes delivered during the award, and qualification by the prime.
- Toolkit usage metered by condition sweep and surrogate training job, so that unit-based and token licensing can be applied.
- Component-level thermal budgets from GVSC and C5ISR programs before a demonstration is sized.

9.4 Frequently asked questions

How large is the market? Estimates for 2024 range from $0.87 to $4.97 billion, and the range reflects the scope each analyst chose. A planning figure should state its scope.

Does the design serve data centers? Accelerator power of 2,300 W is well over the 1.5 kW design point, so the plate area must scale. At 41.7 W/cm² the area for 2,300 W is 55 cm² (computed). Results should also be reported at the 45 °C reference fluid so that buyers can compare them with vendor data.

Can the plate serve radar? Not at the 65 °C inlet, because the case reaches 95 °C against an 80 °C limit. A 50 °C inlet meets the limit at 1.5 kW before module-to-case resistance, and radar heat loads and module-

to-case resistance are open questions.

How do vendor claims compare? Vendors claim 4,000 W single-phase and 4,500 W two-phase cooling. No independent test supports either claim, and buyers may cite them as the reference.

Which route funds the transition? Ceilings range from $167,500 to $30 million. The SBA Phase II guideline is $2.24 million and CATALYST offers up to $15 million. No retrieved source shows that BAA-funded work qualifies for Phase III or the Strategic Breakthrough Award, so the route is an open question.

Who controls the supply channels? Cold plate suppliers are being absorbed by large infrastructure groups, which control channels to the largest customers. No retrieved source gives prices for AI toolkit licensing, so any licensing revenue estimate rests on assumptions.

10. Where Each Role Finds Detail

Table 13 lists the research studies that hold the detail for each role. Each study contains the sources, the computed values and the stated gaps behind the numbers in this guide.

Table 13. Studies to read first, by role

Role	Studies to read first	Evidence
ARL program manager	Limits of Conventional Liquid Cold Plates and Jet-Impingement Crossflow; Engineering Design Under Sparse Data; Test Infrastructure, Validation, and Quality Assurance for AM Thermal Hardware	Government documents and peer-reviewed studies
Vehicle program engineer	Thermal Management Demands of Silicon Carbide Power Electronics in Army Ground Vehicles; Thermal Expansion Mismatch and Power Module Reliability	Army briefings and peer-reviewed studies
University co-investigator	Test Infrastructure, Validation, and Quality Assurance for AM Thermal Hardware; Carbon Fiber Composite Target Plates for High-Heat-Flux Cooling; Program, Teaming, Data Rights, and Compliance Considerations	Peer-reviewed studies, standards and regulations
Research security and contracts staff	Program, Teaming, Data Rights, and Compliance Considerations	Regulations, solicitations and agency guidance
SOL principal investigator and engineers	Engineering Design Under Sparse Data; Surrogate Modeling, Multi-Fidelity Learning, and Optimization for Thermal-Fluid Design; Uncertainty-Aware Neuro-Symbolic AI for Engineering Decisions; Additively Manufactured Jet-Impingement Cold Plates with Interleaved Returns	Peer-reviewed studies and computed benchmarks
Industry partner	Additively Manufactured Jet-Impingement Cold Plates with Interleaved Returns; Carbon Fiber Composite Target Plates for High-Heat-Flux Cooling; Thermal Expansion Mismatch and Power Module Reliability	Peer-reviewed studies, vendor data and standards
Test and validation laboratory manager	Test Infrastructure, Validation, and Quality Assurance for AM Thermal Hardware; Thermal Expansion Mismatch and Power Module Reliability	Standards, peer-reviewed studies and computed values
Transition stakeholders	Markets, Transition Pathways, and Commercialization for Advanced Cold Plates; Program, Teaming, Data Rights, and Compliance Considerations	Analyst estimates, trade reports and funding documents