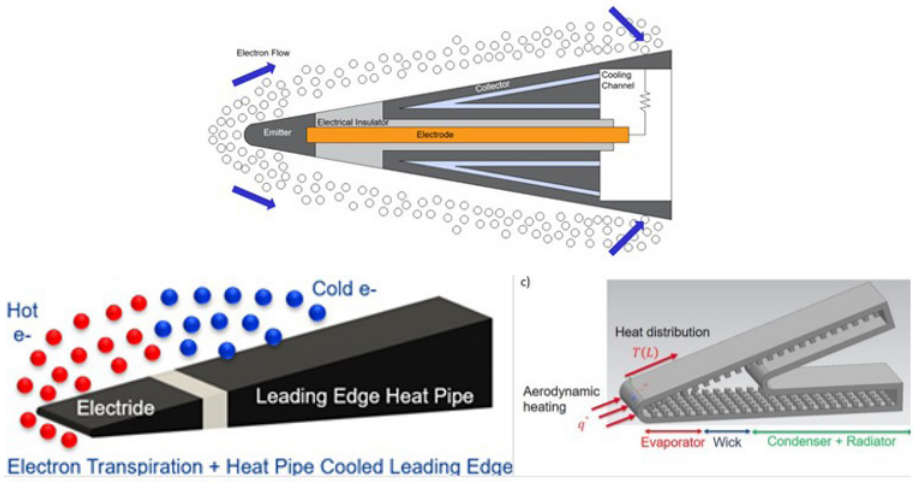
PROJECT SUMMARY 5542.002.001

High-Temperature Applications Using Additive Manufacturing, Phase 2: *Task 2a - Advanced Thermal Management Schemes for Next-Generation High-Velocity Vehicles*



Leading edge design using active electron transpiration leading edge with integrated semi-passive additively manufactured engineered heat pipe.

PROBLEM

The growing risk of other countries challenging the U.S. traditional weapons system has made the development and deployment of high-speed weapons essential. In order to maximize the range and minimize the drag for high-speed weapons, a thin, and sharp leading edge must be employed. Passive/active cooling methods must withstand the ultra-high heat flux and surface temperatures at the leading edge while in the high-speed regime. Limited experimental data of electron transpiration cooling (ETC) models restricts the ability to fully validate existing and in-development computational models of an ETC prototype. In addition, conventional active cooling systems lead to weight increase and potential gas pores blockage due to high stagnation pressures, limiting the range of scramjet engines.

OBJECTIVE

Phase II of this project aims to design, manufacture, and characterize the performance of a leading-edge employing ETC and advanced micro and nano hierarchical liquid metal heat pipe developed during Phase I using additive manufacturing (AM). To test the manufactured leading edge, a high-speed plasma test facility is being designed and manufactured. To further the cooling of the leading edge, the project is focusing on designing, manufacturing, and characterizing the performance of regenerative cooling channels for scramjet engine walls, all of which will benefit next generation high-speed vehicle flights. The project outputs aim to provide high temperature vehicle operation for prolonged exposure and high-Mach numbers.

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to:

DESIGN

ASTM PROCESS CATEGORY
Powder Bed Fusion

EQUIPMENT
EOS M 290, RPM 222

MATERIAL
IN718, Ti64

TECHNICAL APPROACH

The University of Texas at El Paso (UTEP) Aerospace Center is focusing on two areas within this project. The first is the result of sharp, leading-edge active ETC with integrated AM liquid metal heat pipe leveraged from Phase I. The second area of focus is the development of regenerative cooling of the scramjet engine walls using AM cooling channels. For implementation, UTEP is utilizing ground lab tests and virtual tests to work with the Air Force Research Laboratory (AFRL) and commercial high-speed flight testbeds to demonstrate the feasibility of the developed cooling technologies. The approach is to first define the requirements for ETC through a literature review and theoretical analysis of both conventional and AM designs. To test the ETC samples, high-power plasma will be generated by utilizing inductively coupled plasma heaters accelerated through a convergent-divergent nozzle, employing argon or nitrogen gas to generate the plasma. Once successful, testing of AM micro-pillars and zinc oxide nanorods of the sodium heat pipe will occur before complete integrated testing of the ETC and UTEP Keck Center's AM liquid metal heat pipe. Several regenerative cooling channels with variable cross-sectional areas and roughness will also be additively manufactured by the Keck Center and tested to increase forced convective heat transfer.

PROJECT START DATE

April 2023

EXPECTED END DATE

February 2025

EXPECTED DELIVERABLES

- Representative system requirements report
- Analysis report & CAD for design and manufacturing of representative leading edge test coupon for electron transpiration cooling (ETC)
- Analysis report, CAD, materials for design and manufacturing of high-speed plasma test facility
- Excel data & Powerpoint for experimental characterization of ETC on sharp leading edge
- Excel data & Powerpoint for increasing heat pipe performance using augmented structure wickability
- Excel Data & Powerpoint for experimental characterization of integrated ETC-engineered heat pipe cooling performance on sharp leading edge
- Analysis report & CAD for design, fabrication, and characterization of cooling channels
- Excel Data & Powerpoint for investigation of heat transfer performance during forced convection
- Non-proprietary print geometries (if applicable)
- Physical demonstration artifacts
- Final project report

FUNDING

$10,582,407 total project budget
($9,150,000 in public funding/$1,432,407 in private funding)

PROJECT PARTICIPANTS

Project Principal:
The University of Texas at El Paso (UTEP) - Aerospace Center

Other Project Participants:
The University of Texas at El Paso (UTEP) - W.M. Keck Center

Public Participants:
U.S. Department of Defense