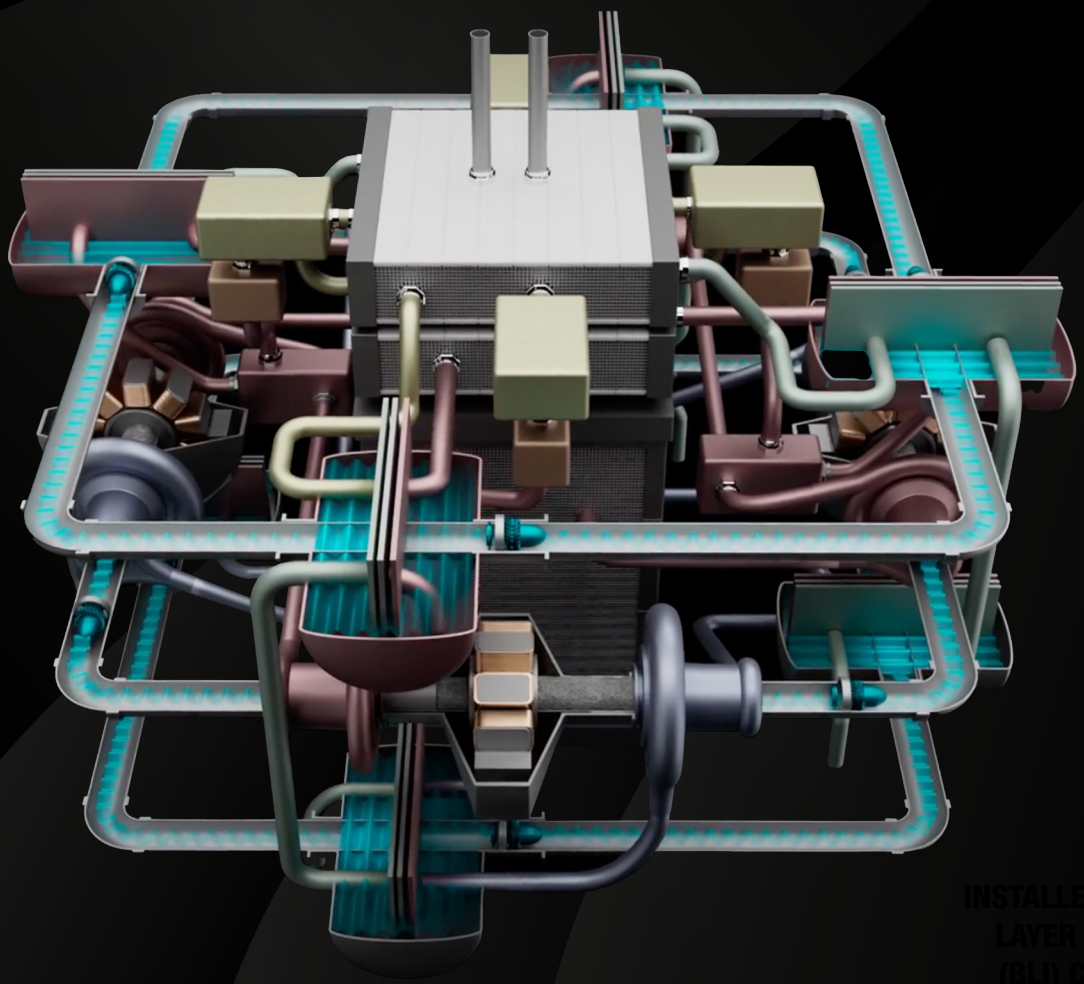
National Aeronautics and
Space Administration

NASA Glenn Research Center

UNIVERSITY STUDENT DESIGN CHALLENGE

2023–2024



TRUE ZERO-EMISSION UNIFIED POWERTRAIN ARCHITECTURE FOR ELECTRIC AIRCRAFT

2023–2024 USDC–8

www.nasa.gov

Table of Contents

1.0 Introduction

The University Student Design Challenge (USDC) hosted by the NASA Glenn Office of STEM Engagement (OSTEM) coordinates with Center scientific and technical staff to identify priority research and technical areas for academic-year-long design challenges. The challenges involve junior and senior student teams of undergraduates in multidisciplinary majors at accredited U.S. universities and colleges. The USDC is an extracurricular opportunity. NASA staff serve as mentors to students during the design process and as judges to select the strongest solution entries for recognition. Research and technology (R&T) development of innovative aerospace- and aeronautics-related technologies at NASA Glenn Research Center (GRC) dates back to 1941. The Center cordially invites student teams to participate in its R&T efforts in the eighth-year implementation of its sponsored USDC (USDC–8) during the 2023–2024 academic year. Students will use nonconventional approaches to solve problems to benefit NASA mission needs. The USDC–8 consists of one aeronautics-themed project, True Zero-Emission Unified Powertrain Architecture for Electric Aircraft.

Eligibility for the USDC–8 competition extends to full-time junior- or senior-year undergraduate students at accredited U.S. academic institutions. Students must be enrolled in multidisciplinary majors in science, technology, engineering, arts, and mathematics (STEAM). Equally eligible are students majoring in economics, marketing, graphic arts, or other disciplines that would aid in successful execution of the Challenge projects. Each team of participating students is required to have an on-campus faculty advisor. The team of students will have access to GRC subject matter experts (SMEs) as off-campus technical mentors to complement on-campus faculty advisors.

As with past-year offerings, the USDC–8 encourages participation by multidisciplinary teams of students with STEAM majors to address societal needs for an optimal use of technical and employable skills to drive and sustain workplace productivity. Application of students' diverse knowledge and resourcefulness is expected to increase team ability and creativity. These applications are also expected to foster teambuilding and communication skills, which will ultimately enhance workplace productivity. The Design Challenge seeks a multidisciplinary view of knowledge to yield varied ideas and feasibilities.

2.0 Challenge Overview

The USDC–8 presents the following Design Challenge option, which focuses on aeronautics:

- Aeronautics Challenge: True Zero-Emission Unified Powertrain Architecture for Electric Aircraft

2.1 Aeronautics Challenge: True Zero-Emission Unified Powertrain Architecture for Electric Aircraft

2.1.1 Problem/Research Background

NASA recently invented a new closed-cycle turbogeneration technology that can achieve true zero emissions while also saving up to 50% fuel consumption. This project will develop a detailed engineering model of the Closed Strayton Quad Generator.

2.1.2 Challenge Goal and Objectives

The goal of this challenge is to design a 70% efficient, 6-kW/kg Closed Strayton Quad Generator system for a 10-MW electric aircraft. The objectives are as follows:

1. Complete the closed Strayton cycle design.
2. Complete the acoustically cooled turbine (Fig. 1).
3. Complete the acoustic quad loop test.
4. Complete the rotating heat exchanger model (Fig. 2).

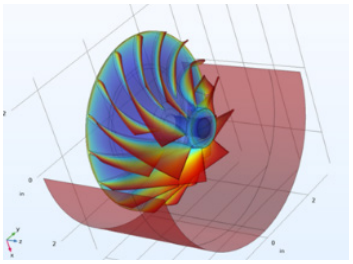


Figure 1. Acoustic Turbine Cooling

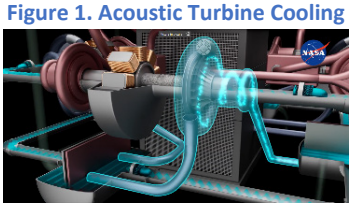


Figure 2. Rotating Heat Exchanger

2.1.3 Mission Performance Requirements

The Closed Strayton Quad Generator concept enables a common electrified aircraft propulsion (EAP) architecture, as shown in Figure 3 and Figure 4, that can save at least 30% fuel burn with a multi-fuel zero-emission power generator, as shown in Figure 5.

A study by the University of Michigan's Michigan Initiative for Sustainable Aviation (MISA), "Conceptual Design Studies of Zero Emission Electric Aircraft Powered by a Strayton Combined Cycle Propulsion System," shows significant fuel burn savings compared to fuel cells and open-cycle turbines:

Table 1. Fuel per passenger-mile (lb/nmi)

H_2 Strayton	Fuel Cells	Kerosene Strayton	H_2 Turboprop	Kerosene Turboprop
0.015	0.0254	0.0371	0.0409	0.0852

2.1.4 Key Considerations

This technology enables zero-emission aircraft without compromising safety or range. The technology is described in the American Institute of Aeronautics and Astronautics (AIAA) paper, "True Zero Emission Electric Aircraft Propulsion Transport Technology" by Rodger W. Dyson (AIAA 2023–3987), selected as AIAA Electric Aircraft Technologies Symposium (EATS) Conference Best Paper in 2023.

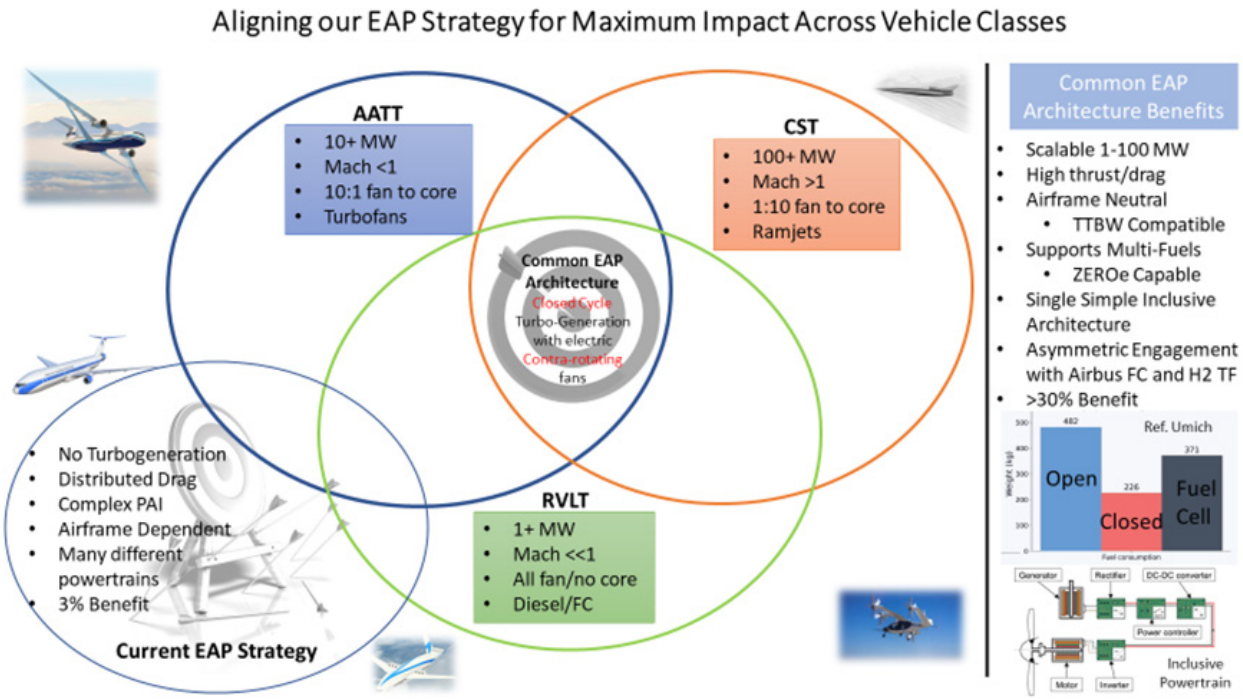


Figure 3. Common Powertrain

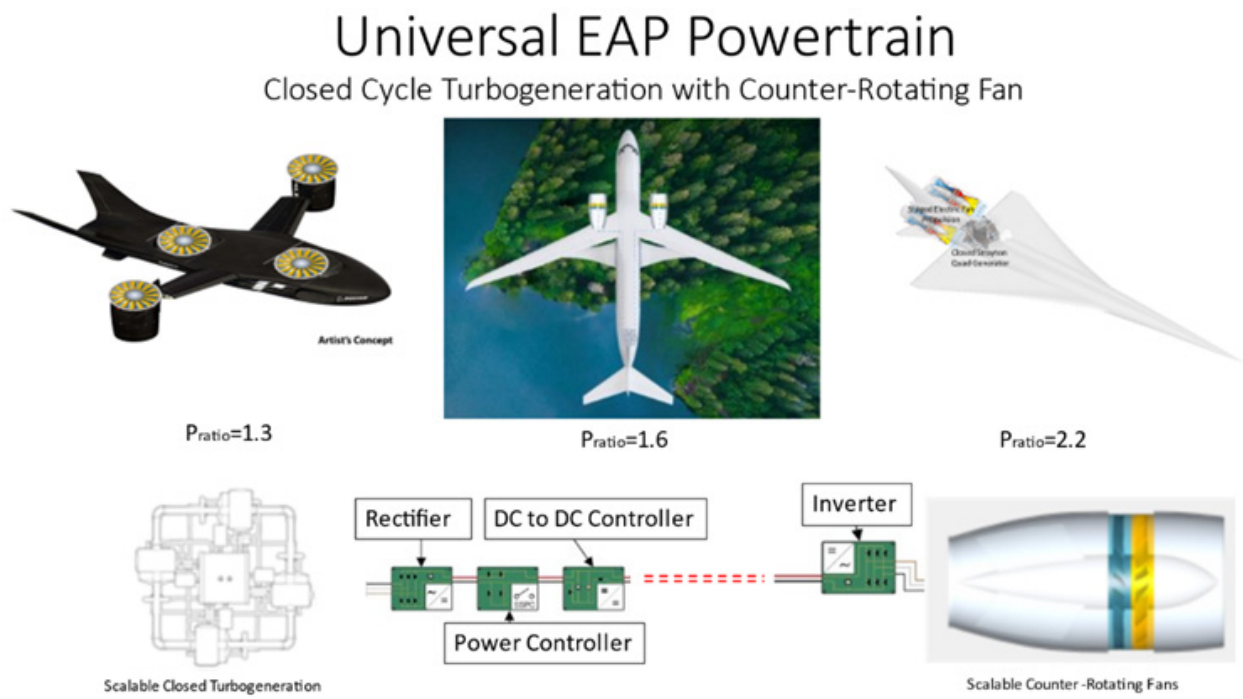


Figure 4. Closed Turbogeneration With Counter-Rotating Fan (CRF)

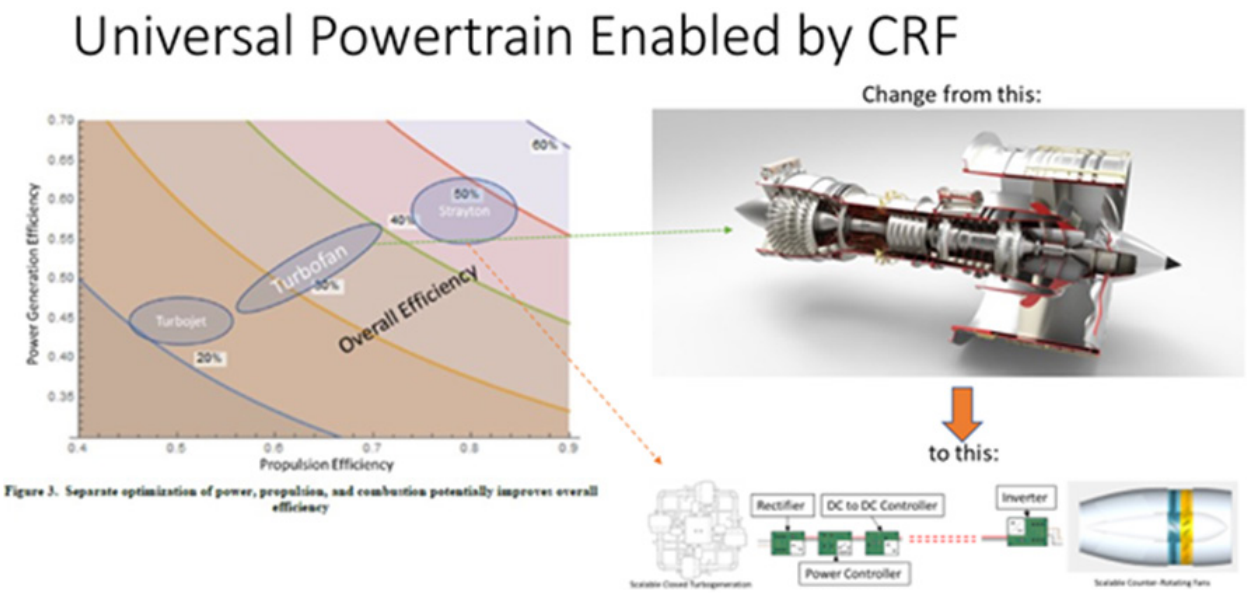


Figure 3. Separate optimization of power, propulsion, and combustion potentially improves overall efficiency

Figure 5. System-level benefit is >30% FBR with convenience of drop-in replacement of existing turbofans

2.1.5 System Design

NASA has established a new electric aircraft propulsion technology category for achieving true zero greenhouse gas emission with transport aircraft. This new category is enabled by a recently invented Closed Strayton Quad Generator and recently developed megawatt-scale electric propulsor motors that enable staged counter-rotating ducted fans in a single nacelle. The new electric aircraft propulsion system described is quiet, clean, efficient, reliable, and safe, and it supports the global transition from jet fuel and sustainable aviation fuel to future green hydrogen fuel with the goal of achieving truly zero impact on the environment. A design of this propulsion system is to be developed.

2.1.6 Literature Resources (As Needed)

Dyson, R.W., True Zero Emission Electric Aircraft Propulsion Transport Technology," AIAA 2023–3987, ntrs.nasa.gov.

NASA Video: Closed Strayton Quad Generator

3.0 Challenge Details

The following information applies to the aeronautics-themed Design Challenge project.

3.1 Schedule and Milestones

Students must register for the Design Challenge competition between October 12, 2023, and November 3, 2023, the registration deadline. Registered students are required to participate in the following scheduled activities and submit the following deliverables:

11/3/2023	Registration Deadline

11/3/2023	Submission Release Form Deadline
11/6/2023 to 11/10/2023	Aeronautics Project Kickoff Presentation and Introductory Workshop I
11/20/2023 to 11/21/2023	Aeronautics Project Virtual Student Team Meeting I with GRC SMEs
1/15/2024 to 1/19/2024	Virtual Preliminary Design Review and Team Photo
2/19/2024 to 2/23/2024	Virtual Pre-Culminating Design Review and Team Action Photo
3/22/2024	Final Design Report and Team Project Video Deadline
4/8/2024 to 4/12/2024	Final Presentations – Teams Present Final Outcomes
4/26/2024	Winners Announced
6/21/2024	GRC On-Site/Virtual Culminating Event – Winning Teams Invited

3.2 Judges and Judging

Each USDC–8 Challenge project will have three independent judges: two subject matter experts (SMEs) and one GRC Office of STEM Engagement (OSTEM) technical staff member with expertise regarding the Challenge projects. The final report and presentation by each team will contribute heavily to the selection of the Challenge winners. The judges, with their collective final decision authority, will select the winning team based on the following:

- Challenge scoring (Section 3.3)
- Compliance with USDC–8 rules and requirements (Section 4.0)
- Compliance with USDC–8 data submission guidelines (Section 5.0)

Judging will be conducted via videoconference using standardized criteria on a scale of 1 (low, poor) to 5 (high, superb). Judges will provide scores to each team within 3 weeks after the final presentations.

3.3 Challenge Scoring

Challenge scores will be based on the judges' assessment of each team's creativity and ingenuity, as well as the feasibility and practicality of their approach, in addressing and/or solving the challenges and issues presented in the USDC–8. Each team's final submission should reflect a high level of quality and effort. Judges are allotted considerable discretion in Challenge scoring. Where data support in a presentation is evident, its inclusion will be factored into the final score for any team.

3.4 Final Submission and Final Presentations (Virtual Culmination)

Each participating team of students shall email their Final Design Report to grc-university-design-challenge@mail.nasa.gov **no later than March 22, 2024.** Team Project Videos are also due on **March 22, 2024**; see Section 4.2 for details.

Each team shall make a 20- to 30-minute virtual final presentation on their design to the USDC–8 judges **between April 8 and April 12, 2024.**

3.5 Culminating Event

Winners will be announced on **April 26, 2024**. Each of the winning teams and their respective faculty advisors will be honored during an event hosted by the NASA Glenn Research Center (GRC). The teams will also make their winning Challenge presentations to an audience of GRC senior leadership and Center personnel, including subject matter experts (SMEs); summer student fellows and interns; and faculty fellows. Please note, meals will not be provided during the Culminating Event or duration of the teams' visit to GRC. Teams are responsible for purchasing their own meals.

4.0 Competition Rules and Requirements

The Final Design Report by each team must reflect attention to the following considerations:

- For Aeronautics Challenge:
  - Design a 70% efficient, 6-kW/kg Closed Strayton Quad Generator system for a 10-MW electric aircraft.
  - Complete the closed Strayton cycle design.
  - Complete the acoustically cooled turbine (Fig. 1).
  - Complete the acoustic quad loop test.
  - Complete the rotating heat exchanger model (Fig. 2).

Student teams must follow USDC rules regarding eligibility, registration, design, deliverables, monitoring, and review.

4.1 Eligibility and Registration

Each team must

- Be composed of full-time undergraduate students in their junior or senior year.
- Be enrolled in an accredited U.S. (including Puerto Rico) academic institution.
- Have a United States (U.S.) citizen as Team Lead/Point of Contact (POC). Other members of each team must be U.S. citizens or a combination of U.S. citizens and lawful permanent residents of the United States.

- Attend the Virtual Kickoff Meeting of their focused Aeronautics project.
- Be composed of no fewer than 3 individuals and no more than 6.
- Have Team Leads/POCs register all team members through their academic institution no later than 11:59 p.m. EST on **November 3, 2023**.
- Have an on-campus faculty member volunteer to serve as advisor for the complete duration of the USDC–8.
- Have all team members complete the Submission Release Form for University Student Design Challenge, located in Appendix C, and return the completed form via email to grc-university-design-challenge@mail.nasa.gov no later than 11:59 p.m. EST on **November 3, 2023**.

4.2 Rules and Considerations

Each team participating in the USDC–8 agrees to:

- Grant NASA unimpeded visitation to its operations and/or worksites to allow inspection of its conceptual design, if needed. NASA may use such visits (virtual or in-person) to verify any team's compliance with stated USDC–8 rules.
- Permit NASA to review any USDC-related information and/or data the team has withheld. NASA may use such data to validate a team's final submission.
- Provide the following in support of social media and press releases:
  - Two photos: One photo of the team with the faculty advisor and one photo of the team in action (e.g., creating design drawings, charts, or quantitative figures). Photos should be at least 1200 pixels wide by 600 pixels high. Photos cannot be blurry or low resolution. No file sizes greater than 3 MB. Stationary team photo with faculty advisor is due no later than **January 19, 2024**. Team action photo is due no later than **February 23, 2024**.
  - Team Project Video: A 2- to 3-minute video that shows the team building or developing their design from start to finish. Use creativity to tell the story of the project. Avoid having one person speaking to the camera the entire time. Do not send a video version of a PowerPoint presentation. Send video as an MP4 file to a medium that will be identified at a later date (e.g., Dropbox or Google Drive). Due date is **March 22, 2024**.

5.0 Data Submission

Each team must follow the submission guidelines below.

5.1 Format

Each team's written report must not exceed 12 pages (excluding appendices and references) and must be received via email by the GRC Office of STEM Engagement (OSTEM) at grc-university-design-challenge@mail.nasa.gov **no later than 11:59 p.m. EST on March 22, 2024**. The report shall follow the template in Appendix B.

Presentation and document submissions shall be in Adobe portable document format (PDF) or Microsoft PowerPoint (PPT), although ***PDF is preferred***. Any handwritten or drawn document(s) shall be scanned and delivered via PDF with a minimum resolution of 400 by 400 dots per inch (dpi).

5.2 Method

All USDC–8 materials, including each team's final submission, shall be sent to this email address: grc-university-design-challenge@mail.nasa.gov.

6.0 Presentation Package

Each Presentation Package shall include a cover page bearing the title of the Presentation, each team member's name, the faculty advisor's name, the academic affiliation, and location. The Presentation Package shall express reference to "2024 GRC University Student Design Challenge (USDC–8)." POCs for each team shall place their initials next to their name.

7.0 Roles and Responsibilities

There are distinct roles and responsibilities for on-campus faculty advisors and GRC-based technical experts, as noted in the following subsections.

7.1 Role of Faculty Advisor

The on-campus faculty advisor

- Advises students on the Design Challenge project and is available on campus to meet with students
- Guides students to achieve goals of the Design Challenge
- Refers students to appropriate institutional resources
- Confirms his or her support via email to grc-university-design-challenge@mail.nasa.gov

7.2 Role of Technical Experts

GRC's highly skilled workforce includes world-renowned researchers, among them rocket scientists, engineers, physicists, and chemists, as well as aviation specialists and others, many of whom will serve as technical experts throughout the Design Challenge. Students will be immersed in NASA-related research and engineering through interaction with these talented,

dedicated, and passionate employees. With countless specializations in numerous fields, the employees at GRC share one goal: working for the public in support of NASA's mission.

Technical experts have the following roles and responsibilities:

- Serve as content specialists
- Serve as Design Challenge judges
- Respond to team questions
- Review Design Challenge project submissions
- Debrief teams if requested

Appendix A—Acronyms and Abbreviations

AATT	Advanced Air Transport Technology
AIAA	American Institute of Aeronautics and Astronautics
CRF	counter-rotating fan
CST	Commercial Supersonic Technology
DC	direct current
dpi	dots per inch
EAP	electrified aircraft propulsion
EATS	Electric Aircraft Technologies Symposium
FBR	fuel burn rate
FC	fuel cell
GRC	Glenn Research Center
kg	kilogram
kW	kilowatt
MISA	Michigan Initiative for Sustainable Aviation
MW	megawatt
NASA	National Aeronautics and Space Administration
OSTEM	Office of STEM Engagement
PAI	propulsion airframe integration
PDF	portable document format
POC	point of contact
PPT	PowerPoint
R&T	research and technology
RVLT	Revolutionary Vertical Lift Technology
SME	subject matter expert
STEAM	science, technology, engineering, arts, and mathematics
STEM	science, technology, engineering, and mathematics
TF	turbo fan
TTBW	Transonic Truss-Braced Wing
U.S.	United States
USDC	University Student Design Challenge

Appendix B—Presentation of Written Report

Title of Report (Cover Page)

First A. Author, Second B. Author, Jr., Third Author
Academic Affiliation, City, State, Zip Code

Faculty Advisor/Academic Affiliation

2023–2024 GRC University Student Design Challenge (USDC–8)
NASA Glenn Research Center
Cleveland, Ohio

Title of Report (Title Page)

The title of your paper should be typed in bold, 18-point type, with capital and lowercase letters, and centered at the top of the page.

Abstract

The abstract should appear at the beginning of your paper. It should be one paragraph long and complete in itself (i.e., not an introduction). It should indicate subjects dealt with in the paper and state the objectives of the investigation. Newly observed facts and conclusions of the experiment or arguments discussed in the paper must be stated in summary form; readers should not have to read the paper to understand the abstract. The abstract should be bold, indented (1/2 in.) on each side, justified, and separated from the rest of the document by two blank lines.

Keywords: Five to seven subject keywords should be listed and separated by commas.

Nomenclature:

Body of Paper

For uniformity, 12-point Calibri font is recommended.

Major report headings should be bold, centered, and numbered with Roman numerals. Subheadings should be bold, flush left, and numbered with capital letters. Sub-subheadings should be italic, flush left, and numbered.

Reports should include the following sections:

I. Introduction/Background

II. Methodology/Approach

III. Discussion of Results/Findings

IV. Conclusions/Recommendations

Appendices (if any)

Acknowledgments

References

Appendix C—Submission Release Form

SUBMISSION RELEASE FORM FOR UNIVERSITY STUDENT DESIGN CHALLENGE

Title of Submission:_____

_____ ("Submission")

Submitter's Name: _____ ("Student")

Submission Team Members (if applicable) ("Student's Team"):

_____

_____

_____

_____

Faculty advisor(s) (if applicable): _____

Name of School _____

School Address _____

City _____State _____ Zip _____ Phone_____

Grade/Level of Study _____

I, the Student, certify that the above Submission, including any text and illustrations, and any ancillary or attendant material, was made, created, or otherwise developed by the Student or the Student's Team and was not copied from another work, photograph, illustration, or website or made, developed, or created by any other person or entity. I understand that the Submission, including any text and illustrations, and any ancillary or attendant material, will not be returned. I give permission to the National Aeronautics and Space Administration (NASA) to use, reproduce, publish, perform publicly, display publicly, prepare derivative works from, and distribute copies to the public of the Submission, including any text and illustrations, and any ancillary or attendant material, and the Student's name, photo, school, and grade/level of study for any and all purposes deemed appropriate by NASA. NASA may distribute the Submission, including text and illustrations, and any ancillary or attendant material, through a variety of media, including, but not limited to, print, television, websites, or any other means, digital or otherwise. NASA may also permit a third party to exercise NASA's rights, including, but not limited to, the right to display or distribute the Submission, including text and illustrations, and any ancillary or attendant material, in a manner NASA deems appropriate. If information from any other person or entity is included in the Submission, including text and illustrations, and any ancillary or attendant material, it is the Student's responsibility to obtain the appropriate permissions for use of such information as provided herein.

Student unconditionally releases, discharges, and agrees to save harmless NASA from and against any and all claims, liabilities, demands, actions, causes of action, costs and expenses, whatsoever, at law or in equity, known or unknown, anticipated or unanticipated, suspected or unsuspected, which Student ever had, now has, or may, shall, or hereafter have by any reason, matter, cause, or thing whatsoever, arising out of Student's participation or efforts in making, creating, or otherwise developing the Submission, including text and illustrations, and any ancillary or attendant material.

This release and any dispute or claim arising out of or in connection with it or its subject matter or formation (including non-contractual disputes or claims) shall be governed by and construed in accordance with the laws of the United States of America, and the Student agrees that the courts of the United States of America shall have exclusive jurisdiction to settle any dispute or claim that arises out of or in connection with this release.

If any provision, or portion thereof, of this release is, or becomes, invalid under any applicable statute or rule of law, it is to be deemed stricken, and the rest of this release shall remain in full force and effect.

Student hereby affirms that he/she is over the age of 18 and has the right to contract in his/her own name. Student has read the above release prior to its execution and fully understands the contents thereof. This release shall be binding upon Student and his/her heirs, legal representatives, and assigns.

_____ _____

(Participant's Signature) *(Date)*

OR

I, _____, am the ***parent or legal guardian*** of the Student and have the right to contract for him/her. I have read the above release prior to its execution and fully understand the contents thereof. This agreement shall be binding upon me and my heirs, legal representatives, and assigns and those of the subject(s) listed above.

_____ _____

(Signature of Parent or Legal Guardian) *(Date)*