National Aeronautics and Space Administration

NASA Glenn Research Center

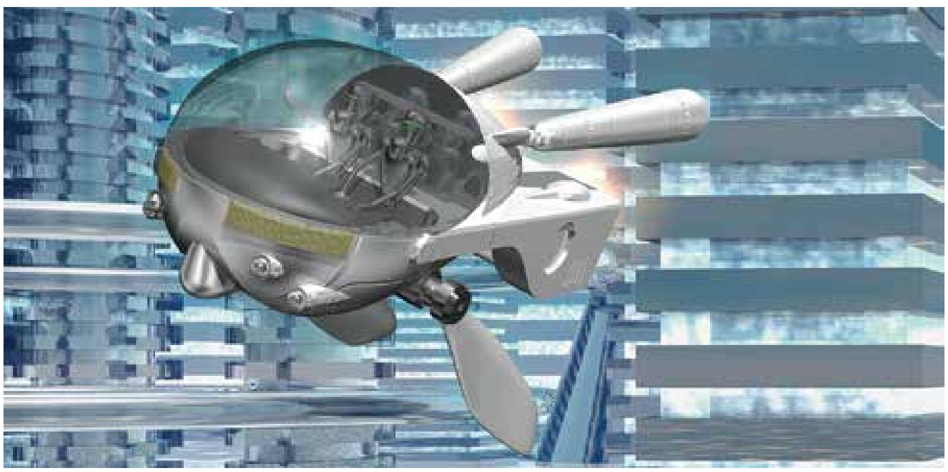
UNIVERSITY STUDENT DESIGN CHALLENGE

2017–2018

NEIGHBORHOODS AND CITIES WITH FLYING CARS AND OTHER VEHICLES

How would a community integrate flying vehicles into a city infrastructure?

AERONAUTICS PROJECT



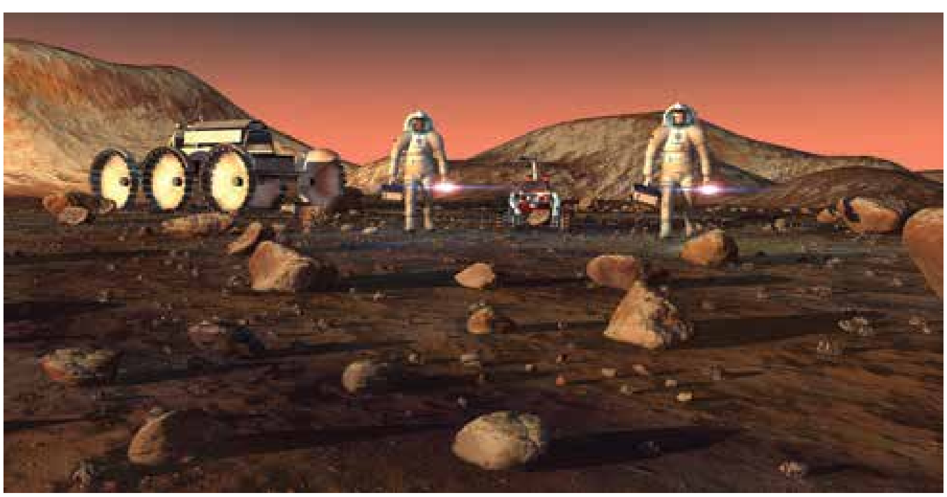
CONSIDERATIONS

- TRAFFIC MANAGEMENT
- AUTONOMOUS OPERATION
- NOISE
- VARIED FLIGHT ALTITUDES
- POWER/PROPULSION
- COST
- SAFETY
- COMMUNICATIONS

HUMANS—A SOLAR SYSTEM SPECIES

How would humans use bioinspired resource extraction to live on Mars or the Moon?

SPACE PROJECT



CONSIDERATIONS

- AUTONOMY
- POWER
- LOW MASS
- DURABILITY
- SIMPLICITY

2018 USDC–2 • Registration Deadline: November 30, 2017 by 11:59 p.m. (EST)

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1.0 Introduction

NASA Glenn Research Center (GRC) has been researching and developing innovative technologies in both aeronautics and space flight since 1941. To encourage undergraduate student involvement in NASA's efforts, GRC is hosting its second-year, two-option University Student Design Challenge (USDC–2) during the 2017–2018 academic year. The USDC–2 is focused on aeronautics and space themes. Participating students are encouraged to apply out-of-the-box approaches to either (a) integrate flying cars into suburban living or (b) conceptually design a space-focused, bioinspired system to extract resources from extraterrestrial bodies such as the Moon and Mars into systems for human habitation in the solar system.

Those eligible to compete in the USDC–2 are full-time junior- or senior-year undergraduate students in accredited U.S. academic institutions and are majoring in multidisciplinary majors in science, technology, engineering, arts, and mathematics (STEAM) disciplines. The USDC–2 is also open to 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 will have access to GRC subject matter experts (SMEs) who will serve as technical mentors for the students.

This USDC–2 promotes participation through multidisciplinary teams of students with STEAM majors to address societal needs for an optimal combination of technical and employable skills to drive and sustain workplace productivity. Using the insights of students with highly diverse knowledge will increase both the ability and creativity of the teams and foster team-building and communication skills, which in turn can enhance workplace productivity. The Design Challenge calls upon a multidisciplinary view to gain knowledge from the resulting ideas and feasibility assessments.

2.0 Challenge Overview

The USDC–2 presents two Design Challenge options, one focused on aeronautics and one focused on space. The aeronautics challenge, described in Section 2.1, challenges student teams to design a suburban city with infrastructure and accommodations for flying cars and service vehicles. The space challenge, described in Section 2.2, challenges students to conceptually design a space-focused bioinspired system to extract resources from extraterrestrial bodies typical of Mars into systems for human habitation in the solar system. Section 3.0 and following provide details common to both challenges.

2.1 Aeronautics Challenge: Neighborhoods and Cities With Flying Cars and Other Vehicles

The future has arrived with the advent of personal flying cars and a number of different remote piloted or autonomous flying vehicles, including small sensing unmanned aerial vehicles (UAVs) that perform such functions as aerial photography, freight delivery of 1,000 lb or more, medical services, and package delivery. The ground infrastructure of roads, highways, and traffic control is the same as today. These flying cars are similar in concept to today's most advanced vehicles. They are manually or autonomously operated in all phases of flight.

The normal methods of flight planning will not work in this new world, as citizens expect to be able to use their flying cars wherever and whenever they like. Filing flight plans and waiting for approval is not considered reasonable. To avoid these problems, city planners have established norms for transit through city airspace, using concepts that are similar to ground transportation. Lanes are established in the sky. Altitudes are assigned for traffic traveling in the same direction. Norms are established for the equivalent of on ramps and off ramps.

The ability of vehicles to automatically sense and avoid other vehicles and hazards is mandated. Vehicles are required to have safety systems to assure safe landings in the event of power or propulsion failure.

2.1.1 Aeronautics Design Challenge Objective

The objective is to design a suburban city with infrastructure and accommodations for flying cars and service vehicles. In so doing, participating students are asked to create plans for the city and its provisions for air vehicles, based on vehicle requirements, communication requirements, traffic system management, and safety. Gaming tools and graphics tools (e.g., Minecraft and SimCity) may be used, as appropriate, to create models of the city. Other considerations of the suburban city are as follows:

- Assurance of safety
- Communication of vehicles with other vehicles around them or other traffic control systems
- Impact of vehicle noise on the system
- System's accommodation of adverse weather

Important characteristics to address include the following:

- How the car operates
- Energy storage and propulsion techniques
- Tradeoffs in weight, performance, and range

Finally, integration of the new air-based system with the current ground intermodal system should be explored, including interaction of ground-based vehicles with the air system.

2.1.2 Mission Performance Requirements

Conceptual design of the city's air traffic system is an essential part of USDC–2. Also, conceptual design of the normal citizen's flying car will be impacted by, and may impact, the city design. Interaction of the noted impacts should be carefully considered.

Vehicle characteristics and performance requirements of the transport can be roughly determined using the above scenario as a guide. Each student design team should consider how an air vehicle can satisfy the requirements of the scenario and determine gross vehicle performance requirements such as passenger- and payload-carrying capability, range, and airspeed. The mission implies that the transport will mimic a private transportation system with stops at places of interest. The scenario implies that the transport should have zero (or near-zero) emissions and noise and, thus, will likely be equipped with some form of fully electric or hybrid electric propulsion with redundant safety features employed.

The aerial system must meet the following technical requirements for communications. Namely, the system must

- Be controllable at all times during operations, by use of a ground link, whether over relay or direct to ground
- Transmit its position in the operational space at a known frequency and identification

- ❖ Be able to perform emergency return home over a preset flight path or safely land upon loss of communication with the control network
- ❖ Not transmit signals outside of its allocated spectrum at any time

2.1.3 Air Vehicle Conceptual Design

Once the transport performance requirements have been defined, student teams need to conceptually design their air vehicles. The design includes choosing a propulsion and power system architecture, modeling and sizing the vehicle, and considering the constraints of operating within a populated area. In order to make their design an improvement on the current transportation architecture, an emphasis should be put on fully electric or hybrid electric vehicles. Student teams should assume the battery energy density is less than 500 kW-hr/kg when sizing their powertrain. Other topics to consider include vertical takeoff and landing (VTOL), short takeoff and landing (STOL), advanced power systems, propulsion–airframe integration, and mixed use of vehicle operation (cargo vs. passenger). Another key decision is whether the vehicle will be piloted, remotely piloted, or capable of autonomous flight. The mode of operation of the transports during weather conditions may impact the design. Student teams should propose solutions for dispatch reliability, icing prevention, and safety.

Teams should note the following dates and address the required subject areas in their analyses:

- ❖ Define mission by Monday, January 8, 2018, and specify
  - ➢ Sample city and infrastructure
  - ➢ Payload, range, and speed
  - ➢ Market research (societal impact, public acceptability of air vehicles, etc.)

- ❖ Begin vehicle design by Wednesday, February 7, 2018, and specify
  - ➢ Airframe design of flying vehicle
  - ➢ Propulsion
  - ➢ Electrical systems and their thermal management
  - ➢ Other major systems and subsystems
  - ➢ Weight and balance assessment
  - ➢ Performance analysis

If gaps or shortfalls in weight or performance are predicted by the analysis, additional technologies may be proposed and used to close the vehicle design. Student teams should be prepared to define what these technologies are and how they will be used. Examples of power systems may include fully electric, turboelectric, or hybrid electric with consideration for safety and redundancy. Examples of propulsion systems may include an electrically driven ducted fan, an open rotor with turbine, some combination of distributed propulsion with geared transmission, and potentially integrating an AC powertrain with double-fed induction motors or a DC powertrain with permanent magnet motors. In addition, novel combinations of quiet heat engines for power and/or propulsion may be advantageous. Alternately, combinations of fuel cells with batteries may provide quiet and reliable power. Student teams should complete a trade study of various powertrain architectures and develop a figure of merit for selecting the optimal system.

Communications play a critical role in assuring the flight safety of aerial vehicles. Aeronautic systems rely on communications for a significant part of their operations. In particular, UAV systems require a design that includes dependable communications. This guide outlines several suggestions for the implementation of such systems by mitigating common development problems. Key topics, potential problems, and possible mitigation strategies are discussed below. It is highly recommended that student teams consider these factors when designing communication systems for the aerial vehicles.

- Importance of Radio Frequency Communication

Radio frequency (RF) communication is the most optimized method for reliable UAV command and control and data transmission and reception. RF systems are small and lightweight, with low power consumption, and are capable of establishing robust communication links over very specific frequencies. The most commonly used frequencies for UAV-related communications and first-person view (FPV) are 2.4 and 5.8 GHz. The 2.4-GHz frequency is often used for connection between the ground control system and the aerial vehicle (AV). This frequency is also used by computer wireless networks, with possible attendant problems when an operator is attempting to fly near office buildings or in other areas with dense network activity. A potential problem encountered is loss of control. Another concern is onboard systems interference during which internal systems of the UAV cause electromagnetic fields that interfere with the RF transceiver, thus effectively jamming any attempts at external control. An example of this would be an FPV signal sent at the same frequency. This type of problem can be mitigated by using 5.8 GHz as a video/data RF link to avoid two signals on the same band. Other common frequencies used for video transmission are 900 MHz and 1.2 GHz.

- Factors Limiting Range of Wireless Link

The range of a wireless link is limited by a number of factors. The path loss itself will diminish the signal when distance increases, and obstacles in the line of sight can give additional attenuation. Also, other radio transmissions in the operational environment can interfere with the command/control/data signal. If the interfering signals occur in the same frequency as the wireless link, it will be observed as noise. This phenomenon reduces the signal-to-noise ratio, causing command and control issues, as well as noisy video images, while limiting the range of the link. Common interferers are other UAVs operating in the area, nearby Wi-Fi transceivers, and cellular phones. This problem can be mitigated by using a channel that is far away in frequency from the interferer, or by physically moving the receiver and antenna.

There are other sources of interference that manifest themselves as powerful signals outside the link. Such signals can penetrate weak front-end channel filtering and affect the performance of the low noise amplifier (LNA). These signals are typically radars, broadcast towers, or military radios. The best course of action here is to operate outside their coverage area.

- Mitigation Strategies

A straightforward mitigation strategy for handling interference is the use of a directional ground antenna to minimize signals coming from other sources. Directional antennas with a narrow beam and high directional gain increase the received strength of the command/control/data signal from the UAV, thus increasing path range of the signal. The antenna can be equipped with a tracker that automatically directs the control signal at the moving system. A tracker takes Global Positioning System (GPS) coordinates from the UAV as input for the antenna's controlled gimbal system and applies a tracking algorithm.

In an environment of a clean and powerful signal, an RF link can get dropouts, especially in urban environments. The cause of the occurrence is the reflected path of propagation of the electromagnetic waves, which cancel the direct propagation path of the original signal at the point of their inverse. The cancellation is also enabled by the phase shift associated with different delays in propagation. This effect can be mitigated by positioning the antenna less than one wavelength from the original or the reflector.

Multipath propagation results in symbol delay spread. In this case, the symbols from the various paths may arrive at different times. This causes bit errors if the delay is long enough that messages carried in the link cannot be decoded properly by the system, with attendant loss of control. The two main strategies to deal with multipath fading are avoidance and constructive combination of reflected signals.

2.1.4 Special Consideration for Noise and Safety

Community noise will be a key consideration. The air vehicle transports will be operating in proximity to neighborhoods. Daytime versus nighttime operations and how well the transportation nodes are insulated from populated neighborhoods are important considerations. Special attention should be given at the outset to low-noise vehicle design and noise metrics. Traditional aviation noise metrics such as those defined by Federal Aviation Regulations[1,2] for airport noise and land-use planning may not be appropriate for flight in and between neighborhoods. After appropriate metrics are defined, reasonable noise limits should be set. An estimate of the vehicle's noise signature should be made, the vehicle should be analytically "flown" at various altitudes, and noise should be predicted for observers on the ground. If a shortfall between predicted levels and set limits exists, student teams should investigate and propose noise-reduction strategies to close the gap. In addition, congested airspace will require redundant safety features in power and propulsion to protect pedestrians and travelers. A reliability analysis should be completed to confirm that the new transportation system is at least as safe as current terrestrial modes.

2.2 Space Challenge: Humans—A Solar System Species

The year is 2050. Rising sea levels and recurring severe weather events have motivated governments to push for Earth-independent colonies in the solar system. The Moon's proximity to Earth makes it an excellent place to develop and refine plans for long-term space settlement operations. Mars at one time in its distant past may have resembled present-day Earth. Water resources will likely be tapped from reservoirs at the lunar poles. Permanently shadowed craters (PSC) with water ice have been discovered on Mercury, and there is also evidence that such water deposits are on the Moon. Resources for propulsion and human persistence in space may be obtained from that water.

"Factories" may be treelike fabrications that use microstructure to transport fluids. Chemicals may be transported through mycelial networks that also serve as building material, food source, and radiation shielding. The push for technology that is environmentally compatible leads scientists to seek answers from nature. Nature-inspired systems are known to minimize resource and energy use while being multifunctional. Consider how natural systems transport fluids and solids. Refer to resources such as www.asknature.org and www.grc.nasa.gov/vine. The bibliography in Appendix D includes other helpful resources.

2.2.1 Space Design Challenge Objective

[1] Federal Aviation Administration (2003): Noise Standards: Aircraft Type and Airworthiness Certification. U.S. Code of Federal Regulations, Title 14, Ch. I, Part 36.

[2] Federal Aviation Administration (2004): Airport Noise Compatibility Planning. U.S. Code of Federal Regulations, Title 14, Ch. I, Part 150.

Conceptual design of a bioinspired system to extract resources from extraterrestrial bodies is the primary objective of the Space-related challenge. System characteristics and performance requirements of the transport can be roughly determined from the environmental conditions on Mars or the Moon and knowledge of the power required to interact with regolith and/or fluids that need to be extracted and/or processed. Student teams are welcome to deviate somewhat from the scope of the given scenario to integrate the resource extraction system into other systems required for human habitation in the solar system. The study should look at what resources are needed, what power is required to extract them, natural models that may apply to the process, and how the natural model may be translated to a mechanical system.

The Martian Atmospheric Chemistry Simulator is a small vacuum chamber that can approximate the pressure, temperature, and atmosphere on Mars. This system could be used for demonstrating proof-of-concept design or solution strategies. Resource extraction systems should be able to demonstrate functionality with simulated regolith. Extracted resources should be accumulated, or a method of verification that the resource was extracted should be shown. Determination of extraction rate and efficiency should be considered.

2.2.2 Mission Performance Requirements

Teams should note the following dates and address the required subject areas in their analyses:

- Define mission by Monday, January 8, 2018, including
  - Optional selection of Mars or Moon as the destination
  - Requirement for resources (human habitat, rover, communication grid)
  - Identification of national and international entities that may need to be involved

- Begin system design by Wednesday, February 7, 2018, with need to specify
  - Natural system discovery and applicability. Identify essential parameters required to scale the problem. Record quantitative information that describes the natural system (e.g., bugs, plants, and fluid transport in other biosystems). Use of International System of Units (SI) is recommended. Data should be stored in an Excel file.
  - System concepts (e.g., Mars water extraction system, inspired by tree roots)
  - System mass constraints (How would one get the material to the place where one plans to use it?)
  - Subsystem definitions (pumps, power source, condensers, excavators, etc.), including power requirements and interfaces
  - Technology required to create subsystems and system (e.g., Do shape memory alloys, nanomaterials, and electroactive polymers exist yet?)
  - Creation of a prototype of each team's system, using resources available to the team (optional)

If gaps or shortfalls in performance are predicted by the analysis, additional technologies may be proposed and used to close the design. Student teams should be prepared to define what the technologies are and how they will be used.

3.0 Challenge Details

The following information applies to both the aeronautics and space components of the Challenge.

3.1 Schedule and Milestones

Students must register for the Design Competition by the November 30, 2017, deadline. Registered students are required to participate in the following scheduled activities and deliverables:

11/30/2017 — Registration Deadline

12/5/2017 — Submission Release Form Deadline

12/5/2017 — Virtual Kickoff Meeting, Aeronautics Project

12/6/2017 — Virtual Kickoff Meeting, Space Project

2/22/2018 to 2/23/2018 — Virtual Preliminary Design Review and Team Photo

3/21/2018 to 3/23/2018 — Virtual Pre-Culminating Design Review and Team Action Photo

4/13/2018 — Deadline for Final Design Report and Team Project Video

4/24/2018 to 4/27/2018 — Final Presentations (Virtual Culmination—Teams present project outcomes)

5/3/2018 — Winners Announced

Date TBD — GRC Culminating Event (Winners invited)

3.2 Timeline for Speaker Series

Presentations on GRC Core Competencies are scheduled to familiarize student teams with broad-based aerospace areas of engagement, some of which are reflected in the stated Design Challenge projects. Students will have the opportunity to view each presentation live; the timeline is noted here. Past presentations will be available via a webcast link during the Competition.

1/18/2018 — Air-Breathing Propulsion

1/31/2018 — Communications Technology and Development

2/12/2018 — In-Space Propulsion and Cryogenic Fluids Management

2/28/2018 — Power, Energy Storage and Conversion

3/08/2018 — Materials and Structures for Extreme Environments

3/29/2018 — Physical Sciences and Biomedical Technologies in Space

3.3 Judges and Judging

Each USDC–2 Challenge project will have three independent judges: two subject matter experts (SMEs) and one GRC Office of Education staff member with technical expertise regarding the Challenge projects. Each team's final report and presentation 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

- Challenge scoring (Section 3.4)
- Compliance with USDC–2 requirements and rules (Section 4)
- Compliance with USDC–2 data submission guidelines (Section 5)

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 of the team's presentation.

3.4 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–2. 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 eventual score for any team.

3.5 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 April 13, 2018.** Team Project Videos are also due on April 13, 2018; see Section 4.2, Rule 2C for details.

Each team shall make a 20- to 30-minute virtual presentation on their design to the USDC–2 judges **between April 24 and April 27, 2018.**

3.6 Culminating Event

Winners will be announced on May 3, 2018. Each of the winning and runner-up teams and their respective faculty advisors will travel to Glenn Research Center in Cleveland, Ohio. First-place teams of the Aeronautics and Space projects will present their design highlights to the GRC Director and members of the Director's senior management staff. The winning and runner-up teams will tour selected GRC facilities and network with GRC personnel following the presentations.

Travel expenses of up to $5,000 per team will be awarded to the winning and runner-up teams if their academic institutions are located outside a 50-mile radius of GRC. Lawful permanent residents of the United States and non-U.S. citizens on the winning and runner-up teams shall adhere to GRC access policies. Please note that GRC may not be able to provide, or may need to restrict, access to some international visitors.

4.0 Competition Rules and Requirements

Each team's final submission must focus on GRC's Core Competencies and address the following considerations:

- For Aeronautics Project: Consideration of energy consumption, noise, emissions, cost, alternative energy, and safety
- For Space Project: Consideration of autonomy, power, low mass, durability, and simplicity

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

4.1 Eligibility and Registration

Rule 1: Eligibility Requirements

Each team must

- Comprise full-time undergraduate students in their junior or senior year.
- Be enrolled in an accredited U.S. (including Puerto Rico) academic institution.

- ❖ Have a 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 or space project.
- ❖ Comprise a minimum of three individuals.
- ❖ Have Team Leads/POCs register all team members through their academic institution no later than 11:59 p.m. EST on November 30, 2017.
- ❖ Have an on-campus faculty member volunteer serving as advisor for the complete duration of the USDC–2.
- ❖ Have all their 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 December 5, 2017.

4.2 Design Requirements

Rule 2: Design Requirements

Rule 2A: Each competing team shall incorporate, to the extent possible, the following features in their design of the air vehicle and propulsion attributes:

- ❖ Reduced footprint for urban operation through use of ducted fans for extremely low noise and short-range intermodal flight to minimize onboard power
- ❖ Compatibility with existing infrastructure, exemplified by all-electric charging at metro rail stations and necessity for low-carbon emission
- ❖ Public confidence in flight safety via use of ducted fan for powered lift

Rule 2B: The submitted design shall include

- ❖ Definition of the mission (sample city or cities) and specification (payload, range, and speed)
- ❖ Information on vehicle design and specification
- ❖ Considerations for noise (abatement)

Rule 2C: Each team shall provide the following items for use in FY18 USDC–2 news and social media announcements:

- ❖ 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 your 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 April 13, 2018.
- ❖ 2 photos: 1 photo of the team with the faculty advisor and 1 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 3MB.

4.3 Monitoring and Review

Each team participating in the USDC–2 agrees to

Rule 3: Grant NASA unimpeded visitation to its operations and/or worksites to allow inspection of its conceptual design, if needed. NASA may use such visits to verify any team's compliance with stated USDC–2 rules.

Rule 4: 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.

5.0 Data Submission

Each team must follow the submission guidelines below.

5.1 Format

Each team's written report must not exceed 30 pages and must be received via email by the GRC Office of Education **no later than 11:59 p.m. EST on April 13, 2018**. The report shall follow the template in Appendix B.

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

5.2 Method

All USDC–2 material, including each team's final submission, shall be sent to this email address: grc-university-design-challenge@mail.nasa.gov.

5.3 Presentation Package

Each Presentation Package shall include a cover page bearing the title of the Presentation Package, each team member's name, the faculty advisor's name, the academic affiliation and location, and express reference to "2018 GRC University Student Design Challenge (USDC–2)." POCs for each team shall place their initials next to their name.

6.0 Roles and Responsibilities

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

6.1 Role of Faculty Advisor

The on-campus faculty advisor

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

6.2 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 projects

Appendix A—Acronyms

AC	Alternating Current
AV	Aerial Vehicle
DC	Direct Current
dpi	dots per inch
FPV	First-Person View
GPS	Global Positioning System
GRC	Glenn Research Center
LNA	Low Noise Amplifier
NASA	National Aeronautics and Space Administration
PDF	Portable Document Format
POC	Point of Contact
PPT	PowerPoint Presentation
PSC	Permanently Shadowed Craters
RF	Radio Frequency
SI	International System of Units
SME	Subject Matter Expert
STEAM	Science, Technology, Engineering, Arts, and Mathematics
STOL	Short Takeoff and Landing
UAV	Unmanned Aerial Vehicle
USDC	University Student Design Challenge
VTOL	Vertical Takeoff and Landing

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

2018 GRC University Student Design Challenge (USDC–2)
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 (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 argument 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:
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

Appendix (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)*

Appendix D—Bibliography

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