

# NASA University Engineering Design Challenge, 2018-2019

## Mission Possible: Self-Piloted Aircraft for Critical Rural/Suburban Needs

NASA invites students to propose very short takeoff and landing, multi-modal commuter aircraft designs that enable increased throughput of passengers and/or cargo in rural and suburban areas. These aircraft can take advantage of cost savings realized associated with cargo operations without requiring a pilot onboard the aircraft. Students are also asked to estimate the cost savings associated with removing the pilot from the aircraft during the passenger missions in future scenarios.

## Background

Commercial operation of small commuter aircraft represents a significant economic challenge to the aviation industry. These aircraft fly what are typically local, shorter-range routes with fairly low passenger demand on any given route, which necessitates fairly small vehicle sizes. Though the individual route demand is low, elimination of these routes may cut off sparse communities on the “long, thin tail” of city-pair demand. These routes are economically challenging for operators due to their type of operation – the low demand lowers utilization (flight hours), which increases the impact of fixed costs (e.g. airframe and insurance costs). Similarly, the short range incurs a high frequency of takeoff and landing cycles, impacting direct operating costs (e.g. fuel/energy and maintenance costs). The low utilization and few number of seats further impacts the cost per passenger, since these high costs are spread over few passenger seats. At high per-seat costs, passengers may take other, less time-efficient means of transportation, further decreasing demand. The economics of some of these routes are so poor that they are subsidized in the United States by the Essential Air Services program [1], to ensure that small, remote communities maintain access to affordable air transportation.

These aircraft are typically sized such that they can be operated under 14 CFR Part 135 [2], which allows them to be operated with a single pilot. This requires that the aircraft carry no more than nine passengers or 7,500 pounds of cargo. These same types of aircraft are typically used for small air cargo operations into these same types of communities. Air cargo is an area that is being explored for early adoption of autonomous flight, given that there are no passengers at risk onboard the aircraft. Air cargo also represents a mission that is typically conducted during times that do not coincide with peak passenger operations. As such, there is an opportunity for the design of a more economically viable aircraft that can service both passenger and cargo routes to increase utilization (and therefore lessen the impact of fixed costs) through daytime passenger operations and late evening/early morning cargo operation. These costs could be further reduced by designing an optionally piloted system – one that is piloted during passenger operations, and remotely piloted or autonomous for cargo operations.

## Design Requirements

Entrants are to design an optionally-piloted aircraft that is otherwise suitable for commuter operation under 14 CFR Part 135, with a planned service entry date of 2025. Some requirements are listed with a **threshold** and a **goal** – the **threshold** is the requirement for minimum success, and the **goal** represents

the preferred value (see “Scoring” at the end of the document). Values in between the threshold and goal are acceptable. Additional background is available in references [3] and [4].

1. The aircraft, in the passenger configuration, shall have a seating configuration of at least nine passengers.
  - 1.1. Passenger weight shall be calculated at 180 pounds, plus 40 pounds of baggage.
2. The aircraft, in the cargo configuration, shall have a payload capacity of at least 2,000 pounds.
3. The aircraft shall be able to convert from the passenger to the cargo configuration in no more than 60 minutes. Similarly, the aircraft shall be able to convert from the cargo to the passenger configuration in no more than 60 minutes.
4. The aircraft shall have accommodations for up to two pilots onboard the aircraft to facilitate training.
  - 4.1. Near-term operations while carrying passengers shall be conducted with a single pilot onboard the aircraft.
  - 4.2. Operations in the cargo configuration may be conducted without pilots onboard the aircraft, if accommodations are made for appropriate control and communications equipment for remotely piloted or autonomous operation.
  - 4.3. Farther-term operations while carrying passengers may be conducted in accordance with Requirement 4.2.
5. The aircraft maximum range, exclusive of reserves, in the passenger configuration, with nine passengers, shall be a minimum (**threshold**) of 200 nautical miles, with a **goal** of 500 nautical miles.
6. In the passenger configuration, with nine passengers, the aircraft shall fly at a speed that enables the maximum range mission (exclusive of reserves) per Requirement 5 to be completed in no more than 99 minutes. Entrants shall be mindful of typical speed limitations that exist in the U.S. national airspace (e.g. cannot fly above 250 KIAS below 10,000 ft MSL).
7. The aircraft shall include enough fuel/stored energy at the end of all missions to accommodate appropriate reserve requirements. This includes:
  - 7.1. Enough energy to sustain a balked landing and a minimum (**threshold**) of a subsequent flight to an airport that is 50 nautical miles away, with a **goal** of flight to an airport at 100 nautical miles away,
  - 7.2. Plus an additional 45 minutes of reserve energy at normal cruise power at the end of the reserve flight segment (defined as the average power setting used during the normal cruise segment of the mission).
8. The aircraft shall be capable of very short-field takeoffs and landings to enable compatibility with future small airparks in otherwise dense suburban areas. **Threshold:** takeoff and landing field length over a 35-ft high obstacle of no more than 1,000 ft, **goal:** takeoff and landing field length of no more than 250 ft over a 35-ft high obstacle.
9. The aircraft shall utilize a propulsion system that does not use leaded fuel.
10. The passengers shall not be exposed to a cabin altitude in the passenger compartment of more than 8,000 ft MSL.
11. The aircraft shall operate at a noise level that allows for operation into future small airparks that may be located in dense suburban areas. The **threshold** noise level shall be less than 80 dB(A), with a **goal** of less than 65 dB(A), per the procedures in 14 CFR Part 36, Appendix G [5].
12. The aircraft utilization, in terms of hours of utilization and revenue miles, shall be calculated assuming the following operational mission constraints, for 300 revenue days/year. The revenue hours and miles that can be calculated per revenue day are given by:

- 12.1. Passenger operations: the number of 120-nautical mile, nine-passenger flights in the passenger configuration that can be flown during a 12-hour/day passenger-carrying time period, with a 45-minute turnaround time between flights. Flights shall be flown at or above the average block speed established in Requirement 6 (even if this speed was based on a longer range per Requirement 5). Only an even number of flights may be flown (to allow the crew to return to their “home base”). For simplicity, assume that every flight has one turnaround time segment (the first flight will have  $\frac{1}{2}$  the turnaround time for loading, and the last flight will have  $\frac{1}{2}$  the turnaround time for unloading).
- 12.2. Cargo operations: the number of 120-nautical mile, 2,000-pound payload flights in the cargo configuration that can be flown during a 6-hour/day cargo-carrying time period, with a 30-minute turnout time between flights. Any block speed may be used. Only an even number of flights may be flown, to ensure that the aircraft is at its “home base” for maintenance and subsequent passenger flights. For simplicity, assume that every flight has one turnaround time segment (the first flight will have  $\frac{1}{2}$  the turnaround time for loading, and the last flight will have  $\frac{1}{2}$  the turnaround time for unloading).
13. The aircraft shall have a low life cycle cost (including acquisition & interest, insurance, maintenance, fuel/energy, pilot/operator salary, and other necessary costs), assuming the utilization calculated as above. The life cycle cost shall be expressed in 2018 dollars, with a **goal** of minimizing cost per seat mile (“\$0.00”). “Mile” in this case refers to nautical miles.
  - 13.1. Cargo operations can be included in the cost per seat mile calculation as nine full passenger seats.
  - 13.2. For calculation of manufacturing costs, entrants shall assume a market for a production run of 800 aircraft over 8 years.
  - 13.3. **Goal:** entrants may estimate any changes to the mission, as well as seat-mile cost, for moving the aircraft towards operation with no pilot onboard the aircraft for any of the missions (passenger or cargo). This can include use of existing optionally-piloted equipment, to complete removal of the vehicle cockpit.

## Design Paper

The paper is limited to 25 pages and should include a discussion of the design requirements, including the identification of the driving design requirements and derived requirements. All assertions, technology assumptions, and other relevant information shall be adequately referenced. A systematic process shall be used to provide justification for the final proposed concept. All tools and methods utilized to design and analyze the concept should be briefly described, including tool validation and verification of results utilizing sanity checks, rules of thumb, historical data, etc.

Dimensions, weights, and key performance parameters of the selected concept aircraft shall be presented. At a minimum, the following data shall be provided for the proposed concept(s):

- Dimensioned three-view drawings;
- List of key technologies and justification that they will be available for use;
- Table summarizing compliance with the Requirements;
- Tables showing weight build-up for concept aircraft, including structures weight (wing, fuselage, tails, etc.), propulsion system weight, payload, energy storage, etc. Table should include empty

weight, zero fuel weight (empty weight + payload weight), and takeoff gross weight, for the sizing, passenger, and cargo configurations;

- Tables and/or Figures summarizing key mission parameters for concept aircraft, such as takeoff and landing distance, climb and descent rates, cruise speed and altitude, aerodynamic and propulsion system characteristics (e.g., L/D, energy consumption rate), energy consumption by mission segments, and total mission energy use, for the sizing, passenger, and cargo missions;
- Concept of operations for the typical passenger and cargo flights referenced in Requirement 12, including any required ground operations;
- Mission schedule over a 24-hour duty period, considering the operational tempo given in Requirement 12, and discussion about the adequacy of the remaining time period (reserved for conversion between cargo and passenger configurations, light maintenance/servicing, repositioning, etc.);
- Description of optionally-piloted system and operating modes. If entrants elect to pursue Requirement 13.3, they should describe the changes that would be necessary to the aircraft, as well as any potential ancillary issues that may arise (or be removed) with complete removal of an onboard pilot for passenger-carrying operations.
- Description of design features used to minimize exposure to predictable hazards and failures (e.g. propulsion unit failure during critical flight phases, energy system failures/contamination, etc.).

## Scoring

Entries will be scored based on the overall credibility of the approach, as well as by the degree that the students exceed any **threshold** requirements. Credit will not be given for exceeding any of these requirements beyond the stated **goals**. As always, judges will reward outstanding technical communication skills, creativity, imagination, and demonstration of exceptional skill and ingenuity.

## References

1. U.S. Department of Transportation, "Essential Air Service," <https://tinyurl.com/y7w7t8j5>, accessed 22 August 2018.
2. Federal Aviation Administration, "14 CFR Part 135 Air Carrier and Operator Certification," <https://tinyurl.com/y8alt3dn>, accessed 22 August 2018.
3. D. Wolf, "Commuter Airline Perspective," presented at ODM and Emerging Technology Joint NASA-FAA Workshop, Arlington, VA, May 8-9. Available at <https://tinyurl.com/yat134eq>, accessed 22 August 2018.
4. A. M. Stoll, G. Veble Mickić, "Design Studies of Thin-Haul Commuter Aircraft with Distributed Electric Propulsion," AIAA 2016-3765, 16<sup>th</sup> AIAA Aviation Technology, Integration, and Operations Conference, AIAA AVIATION Forum.
5. Government Publishing Office, "Appendix G to Part 36—Takeoff Noise Requirements for Propeller-Driven Small Airplane and Propeller-Driven, Commuter Category Airplane Certification Tests on or After December 22, 1988," <https://tinyurl.com/y7m8tukn>, accessed 22 August 2018.