Revision:	v3.0, 12 December 2023	
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DM1F-GPO-008001
Dutch Caribbean Electric Aviation Initiative Final Report

Executive Summary

Ampaire was awarded a contract by the Directorate-General for Aviation and Maritime Affairs within the Dutch Ministry for Infrastructure and Water Management, to deliver a first phase study that is anticipated to become a multi-phase project. The overall goal is to enable more environmentally friendly flights between, and potentially increased connectivity to, the southern Dutch Caribbean islands, whilst setting up the ecosystem in the region to be at the forefront of the transition to the next age of aviation. This can be achieved with emerging electrified aviation by leveraging the lower direct operating costs and the resulting reduced emissions of hybrid flight.

This document presents the results of the studies conducted for Phase 1 of the project including route assessments, planning, and modeling, ABC Islands infrastructure, the logistics of operating Ampaire's Hybrid Caravan in the region, the training and maintenance capabilities required to support pilot operations, and regulatory requirements to conduct the proposed operations.

As a result of this extensive study, it was concluded that pilot operations in the region are feasible with the Hybrid Caravan. The island airports are ready to support Hybrid Caravan pilot operations with adequate aircraft shelter and battery pack charging capabilities using the standard Ampaire charger. They are already making changes to infrastructure and choosing renewable energy sources for their power grids to position themselves for the future. There are personnel present with existing training in 9-passenger aircraft maintenance who are available to support Hybrid Caravan aircraft maintenance and require only electrified aircraft training and Hybrid Caravan orientation to work alongside Ampaire's team. Through regulatory research, it was determined that the Hybrid Caravan can safely fly pilot operations in the ABC Islands and the requirements are well understood.

Phase 2 is the implementation of the Phase 1 plan, where the Hybrid Caravan is repositioned to the ABC Islands, then maintained and flown by Ampaire with local partners working alongside our subject matter experts, gaining experience with electric aircraft maintenance and operations. This is the phase where extensive data are gathered, data validation occurs, training is developed, and initial training conducted.

Ampaire have developed a high-level plan for phase 2, as explained in more details in paragraph 1.3. This plan is made for the ideal situation where a start is possible directly after closing phase 1, with an associated estimated cost of $6,437,529 USD and duration of 20 months. In regard to continuing with this

plan, a definitive decision cannot be made at this time. The following table shows the high-level breakdown of the estimated cost. A detailed proposal can be developed if required.

Labor	$	4,765,131
Material	$	845,000
subcon	$	710,200
T&S	$	83,560
Other	$	33,638

Table 1 - Phase 2 Estimated Cost and Duration

Phase 3 would entail the preparation of the ABC Islands aviation ecosystem for full scale electrified aircraft operations. It would build upon the findings and learning from Phase 2 Pilot Operations and the relationships cultivated with local operators and airport decision makers.

List of Distribution

Ampaire – CTO	Ed Lovelace
Ampaire – Project Team	All
Persoonsgegevens	Persoonsgegevens
	Persoonsgegevens

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Terms, Acronyms, and Abbreviations

Term	**Definition**	**Notes**
3S	Saba, Sint Eustatius, Sint Maarten	A reference to these islands
A&P	Airframe and powerplant aircraft mechanic	FAA
A&P IA	Airframe and powerplant aircraft mechanic with an inspection authorization certification	FAA
ABC	Aruba, Bonaire, Curaçao	The Dutch Caribbean islands researched for this report
AC	Alternating Current	
ADCUS	Advise Customs (US)	
AMT	Aviation Maintenance Technician	EASA
AMT	Aviation Maintenance Technician School	EASA
ASM	Available Seat Mile	Refers to how many seats on a plane on a given route are actually available for purchase on an airline
ATC	Air Traffic Control	
ATM	Air Traffic Management	
AUA	Aruba Airport	Reference
BATD	Basic Aviation Training Device	
BN	Britten-Norman	Type of aircraft
C	Current	1C = a fully charged battery
CAA	Civil Aviation Authority	
CEO	Chief Executive Officer	
DC-ANSP	Dutch Caribbean Air Navigation Service Provider	
DCCA	Dutch Caribbean Cooperation of Airports	
DCEA	the Dutch Caribbean Electric Aviation Project	The project reported within this document
DOC	Direct Operating Cost	
eAIP	Electronic Aeronautical Information Publication	
EASA	European Union Aviation Safety Authority	

EPS	Electric Propulsion System	
EPU	Electric Propulsion Unit	The combination of an electric motor and inverter
FAA	Federal Aviation Administration (U.S.)	
FBO	Fixed Base of Operations	
FCC	Federal Communications Commission (U.S.)	
FF	First Flight	
FM	Fundashon Mariadal	A hospital at Bonaire supporting information gathering for this project
GPH	Gallons per Hour	
IASA	International Aviation Safety Assessment	(Program), FAA program in partnership with CAA organizations around the world dedicated to meeting ICAO standards
ICAO	International Civil Aviation Organization	promotes the safe and orderly development of civil aviation around the world
IenW	Ministerie van Infrastructuur en Waterstaat	
IFR	Instrument Flight Rules	Flying during times of limited visibility, such as bad weather
ILT	Inspectie Leefomgeving en Transport	Performing the Netherlands CAA function
IMC	Instrument Meteorological Conditions	Weather that requires the use of instruments, typically cloudy or low visibility
ISA	International Standard Atmosphere	
KLM	Koninklijke Luchtvaart Maatschappij N.V.	
MOU	Memorandum of Agreement	
MRO	Maintenance, Repair, and Overhaul	Usually used to refer to an organization that carries out these activities
MTOW	Maximum Takeoff Weight	
NACC	North American, Central American, and Caribbean	

NM	Nautical Mile	
nmi	Nautical Mile	
NPA	Notice of Proposed Amendment	
PIC	Pilot in Command	
PJG VOR	Identifier of the ground navigation instrument near the Curaçao airport	
PPE	Personal Protective Equipment	
RC	Radio Controlled	
SAF	Sustainable Aviation Fuel	
SSS	Saba, Sint Eustatius, Sint Maarten	
STC	Supplemental Type Certificate	For aircraft
TC	Type Certificate	For aircraft
TNCA	Airport designator for Aruba	
TNCB	Airport designator for Bonaire	
TNCC	Airport designator for Curaçao	
US	United States	
USD	United States Dollars	
VFR	Visual Flight Rules	Flying during the day or night when visibility is good
VOR	Variable Omni Range	A ground navigation instrument for aircraft
WEB	Water-en Energiebedrijf Bonaire	

1. Project Introduction

Ampaire was awarded a contract by the Directorate-General for Aviation and Maritime Affairs within the Dutch Ministry for Infrastructure and Water Management to deliver a first phase study that is anticipated to become a multi-phase project: the Dutch Caribbean Electric Aviation Project. The overall goal is to enable more environmentally friendly flights between and potentially increased connectivity to the southern Dutch Caribbean islands by leveraging the reduced emissions and lower direct operating costs (DOCs) associated with electrified aviation, while setting up the region in terms of skills and infrastructure to be at the forefront of the transition to the next age of aviation.

Phase1 concluded in November 2023 and was an investigation into the work needed from a complete ecosystem perspective to allow for successful pilot operations of Ampaire's Hybrid Caravan hybrid-electric aircraft (https://www.ampaire.com/vehicles/eco-caravan) within the ABC (Aruba, Bonaire, Curaçao) Island region. The Hybrid Caravan is a retrofitted Cessna Grand Caravan that consists of a hybrid powertrain with a type certified combustion powerplant. The retrofit allows for a reduction of fuel and emissions of over 50% and up to 90% emissions reduction using sustainable aviation fuel (SAF).

Phase 2, as currently planned, consists of carrying out the actual pilot operations within the islands, while also progressing the skills development alongside that in the form of maintenance training and education engagement. The project will not only cover passenger travel but also medical and cargo delivery, through our relationship with Fundashon Mariadal. Maintenance training aspects are carried out in partnership with KLM MRO function both within this project and more broadly under the terms of our MOU with them (https://www.afiklmem.com/en/press-release/18102022-ampaire-and-afiklmem-lay-the-foundations-to-advance-electric-aviation).

1.1. Project Objectives

The objectives of this project are to perform pilot operations of the Hybrid Caravan aircraft and to pave the way for the Dutch ABC islands to be become first adopters of electrified commercial flights in the world by:

1. Identifying necessary changes in the regulatory, operational procedures including training and skills needed,
2. Validating the cost and environmental benefits of utilizing Ampaire's Hybrid Caravan aircraft for inter-island operations; and
3. Showing power/energy (renewable) access and verify demand growth to be planned.

To carry this out, there are various options to be considered and investigated within the project such as the right partnerships (stakeholders), routes (e.g., for airline passengers or cargo, or for ambulance; frequencies for economic viability), and mission profiles.

The lessons and insights can be broadly shared with the ABC Islands community, the Netherlands sustainable aviation community, and aerospace industry at large.

Currently, there is no bi-lateral agreement between FAA and EASA on the regulatory requirements and standards for this new class of aircraft with hybrid-electric technology. The Hybrid Caravan will have an initial FAA type certification, known as a Supplemental Type Certification (STC), for the new propulsion and energy system in addition to the aircraft's original certification; but the EASA ruleset will also need to be adhered to for operations within the islands (and mainland Europe).

Moreover, the operations of these aircraft might also be different than aircraft of a similar/equivalent class. For example, the Hybrid Caravan can be thought of as a "1.5-engine" aircraft instead of a single-engine aircraft due to the fuel engine and electric engine combination. Even so, improved safety and reliability of systems are not currently well understood. The pilot operations planned for Phase 2 provide the opportunity to use real data analytics to identify and validate the changes required to shepherd in this new age of aviation. The Phase 1 study charts the course in this effort and lays out the plan to ensure a safe and productive pilot program.

Other goals met for Phase1 included planning with potential partners and stakeholders, such as KLM airlines and the KLM Engineering and Maintenance (E&M) group and smaller operators (e.g. Divi Divi), to analyze flight routes, support services, and airline operations; compare costs between conventional powered aircraft and our retrofit hybrid-electric powered configuration, and project future operational scenarios for healthy inter-island air transport with anticipated emission reduction. Similarly, for other missions, such as ambulance or medical supplies, Ampaire consulted with Fundashon Mariadal (FM) to better develop the mission profile to meet the demand of the island community more economically, including the potential of safely connecting to South American facilities (note the current range of the aircraft is able to cover parts of South America but may be at slightly less payload for safety margin).

Additionally, with the ambitious infrastructure development plan starting with the DCCA's MOU signed by 15 entities in 2022, the Bonaire International airport was awarded $21 million for upgrading airport infrastructure and was in the first step towards developing a charging infrastructure by the Ministry of Infrastructure and Waterways Management. This leadership in infrastructure development would need a full eco-system's participation in concept proving and scale up towards an actual operational plan.

The third goal in this project was to work with the Bonaire airport and the other Dutch Caribbean airports to utilize their new charging and energy storage infrastructure to provide real-time inputs and realistic user-requirements in future projections. This development must be planned thoughtfully as cost and schedule will need to support the operations plan. Most importantly, the operations at the airport will require the (airplane) operators, airport layout, and operational procedures including first responders such as fire rescue etc. development progressing collaboratively to ensure the safety and efficiency of the operations. The Phase 1 study maps out the flight routes, frequencies (working with the operators), and locations of charging and energy storage per operational requirements, as well as the first responders (fire rescue etc.) procedures; making this the "first" of the world's realistic (commercial passenger/cargo aircraft and route) demonstration of hybrid-electric flight.

Ampaire has been successfully flying our technology demonstrator, a hybrid-electric conversion of the Cessna 337, for over 3 years, and this project will potentially be the very first pilot operations of the Hybrid Caravan model.

1.2. Phase 1 Work Packages

The Phase 1 project comprises multiple work packages, described as follows

WP1: Project Management

WP2: Route Assessments

WP3: Infrastructure Studies

WP4: Logistics for Phase 2 Aircraft Transport

WP5: Training and Maintenance

WP6: Regulatory and Demonstration Flight Planning

WP1: Project Management

WP1 is the general project management work package for the project. The work package includes stakeholder development, the creation of a Phase 2 plan initial draft, and final project reporting/ presentation.

WP2: Route Assessments

The potential commercial benefits of flying the Hybrid Caravan within the ABC islands will be assessed through WP2. The work package is structured such that a preliminary study, based on existing models will be carried out early in the project to help focus other work packages. The analysis will become more extensive throughout the project as more detailed information is gathered through stakeholder engagement and the model is refined.

WP3: Infrastructure Studies

An analysis of the charging infrastructure needs to carry out demonstration testing of the Hybrid Caravan within Phase 2 of the project within the ABC islands, along with proposals for any improvements.

WP4: Logistics for Phase 2 Aircraft Transport

A trade study into the best way to get the demonstration aircraft from California to the Islands, which could be flying the aircraft, shipping it in containers, or any other method.

WP5: Training and Maintenance

A detailed work package involving close collaboration with KLM under the terms of the Ampaire-KLM MOU. There are 2 main strands of activity:

1. To establish the training and maintenance needs to support a Phase 2 demonstration flight.
2. To scope out the broader training and maintenance related activities to be carried out during Phase 2, to ensure that the education, training, and maintenance environment is prepared for a future involving electrified flight and to pave the way for young people to be able to enjoy a career in the sector, within the ABC islands.

WP6: Regulatory and Demonstration Flight Planning

The ambition is that the Hybrid Caravan will perform pilot operations between the islands during 2024. Within this work package we carry out the practical planning steps to enable that, such as route planning, demonstration flight planning, noise survey planning, and CAA engagement to understand the permit to fly processes.

1.3. Phase 2 Work Packages

Ampaire have developed a high-level plan for phase 2. To maintain familiarity with the work package structure of Phase 1, a similar WP structure is proposed for Phase 2.

WP1: Project Management

WP2: Route Assessments

WP3: Infrastructure

WP4: Aircraft Procurement, Retrofit, and Transport to the ABC Islands

WP5A: Maintenance Training

WP5B: Pilot Training

WP5C: Mainstream Education

WP6A: Regulatory

WP6B: Dutch Caribbean Pilot Operations

Delivery of these work packages are estimated to cost approximately $6,437,529 USD with a duration of 20 months. In regard to continuing with this plan, a definitive decision cannot be made at this time. The following table shows the high-level breakdown of the estimated cost. A detailed proposal can be developed if required.

Labor	$ 4,765,131
Material	$ 845,000
subcon	$ 710,200
T&S	$ 83,560
Other	$ 33,638

Table 2 - Phase 2 Estimated Cost and Duration

These costs cover the labor to deliver all work packages and aircraft preparation work, an aircraft usage fee (monthly fee including maintenance, depreciation, etc.), general supplies/equipment, fuel fees, ferry flights, noise testing, simulator development, CAA approvals, landing fees, and travel costs. Further details are provided in the WP descriptions below.

Note that these costs **do not** cover the hybrid Caravan aircraft development or certification program activities (other than the CAA engagement required specifically to carry out phase2 pilot operations between the islands), both of which would be undertaken separately by Ampaire at Ampaire cost. Nor do they include the purchase of an aircraft for the project, which would also be handled outside of this phase 2 project.

WP1: Project Management

The project management work package captures all high project level stakeholder engagement activities and regular meetings. Deliverables that summarize information from multiple work packages are also contained within this work package.

Deliverables for this WP would include an aircraft financing agreement for leasing the Hybrid Caravan, a DCCA Conference 2024 presentation, and preliminary and final Phase 3 plan.

WP2: Route Assessments

During Phase 2, Ampaire would work closely with multiple island operators to accurately match passenger and cargo routes and expand the DOC model's capabilities for these assessments. Validation of the model would be completed by flying the routes in tandem with the flight planning tasks in Work Package 6 and will also inform the logistics for preparing the aircraft to send to the islands in Work Package 4.

To help validate the model, a number of sensors and data acquisition components that make up a data acquisition system would need to be acquired and installed on the aircraft to collect data. These components are not typically installed on the baseline aircraft or under conventional operations. After the flights, these data are collected and used to update the DOC model and validate or correct operation assumptions.

Additional analysis of the model could be done on other types of operations in the islands and, if requested, routes on the 3S Islands may be completed.

Deliverables for this work package would consist of an expanded model with variables for all operation types and Island specific costs, a validation plan for model including specifications for required aircraft modifications for data collection, a report of results in costing and emissions for routes investigated, and a report of recommendations for flying the Hybrid Caravan in the most cost effective/ sustainable/ fuel efficient way.

WP3: Infrastructure

Ampaire has communicated our infrastructure needs to our point of contact at each airport for Phase 2 pilot operations. We intend to work with each airport to clarify the infrastructure needs of the Hybrid Caravan as aircraft development occurs and will provide details and timelines for airport planning purposes. A significant part of Phase 2 pilot operations is to collect information from operation actuals and refine infrastructure requirements for each island. Likely, we can work around infrastructure gaps during Phase 2 pilot operations, but before going into commercial service in Phase 3, the identified basic infrastructure must be in place and scalable.

Deliverables for Work Package 3 would consist of a Q1, Q2, Q3, and Q4 infrastructure update and progress report for all ABC Islands airports, a final infrastructure update and progress report for all airport, a mid-2024 Phase 2 Pilot Program Infrastructure Risk Assessment, and a Phase2 Preliminary Masterplan.

If there is interest and budget available, an SSS Islands infrastructure assessment plan and SSS Islands infrastructure assessment and recommendations could also be developed and delivered.

WP4: Aircraft Procurement, Retrofit, and Transport to the ABC Islands

Ampaire will acquire the baseline Caravan and modify it for Phase 2 Pilot Operations in the ABC Islands. This entails final design approvals, making sure that the aircraft meets all operational requirements for the Islands, and then the installation of the hybrid AMP Drive™ into the aircraft. As time draws near to reposition the Hybrid Caravan to the ABC Islands, Ampaire will revisit its assessments and options to assure that the planned way forward is still the best value.

The deliverable for this work package Is the Hybrid Caravan's arrival in the ABC Islands for Pilot Operations.

WP5A: Maintenance Training

This work package depends on Ampaire's training curriculum development for the hybrid system that supplements an A&P mechanics standard training. During Phase 2, Ampaire intends to create and validate the specific material required to train a technician to work on Ampaire's Hybrid Caravan. Ampaire intends to validate and test the basic curriculum on the islands with local students and technicians during both Phase 2 and Phase 3 as more curriculum is developed.

This work package also includes training that does not involve maintenance but is related to safety when handling the aircraft, consisting of fire safety training created by Ampaire and validated through the fire brigades on each of the three islands. This training will involve methods to combat battery and electric fires and emergency procedure specific to electric aircraft.

Deliverables for this work package would include a draft and final theory section of type training for the Hybrid Caravan, a draft and final practical section of type training for the Hybrid Caravan, "Train the Trainer" instruction where the first instructor undertakes type training, a written report and plan for validation of the training on the islands, updated training plans after feedback from students and instructors is received after first testing, a written report on results from testing curriculum and training, and a written report on plan for future training activities in Phase 3.

WP5B: Pilot Training

While Ampaire will not significantly change the 'flyability' of the aircraft by retrofitting to a hybrid configuration, there will be differences in cockpit display, throttle controls and stems that will require pilots to undergo flight training before flying the aircraft. Any pilot who intends to fly the Hybrid Caravan will require supervised flying time and simulator time. This work package includes development of a flight simulator and the plans for flight training in the Hybrid Caravan.

Deliverables for this work package include creation of a Level 1 flight simulator that fully matches flight characteristics of the Hybrid Caravan in Xplane or an equivalent software package, creation of flight training plan which will be used to train pilots from operators on the islands, creation of a Level 2 flight simulator, a report on testing of flight simulators, a report on requirements and hardware/software specifications for a fully certified BATD simulator, and a report on plan to create a BATD simulator.

WP5C: Mainstream Education

Ampaire intends to work with the universities, secondary education on the Islands, and select Universities in the mainland Netherlands to create events and advise on student research projects to aid in understanding of electric aircraft. The Phase 2 activities promote educational outreach and include small, student-led activities sponsored by Ampaire such as noise testing and competitions and events for students like drone development and electric propulsion projects. Ampaire also intends a lecture series hosted at universities and education institutions in the islands on topics that include Infrastructure requirements for electric aviation; electric powertrains – theory, operation, testing; batteries – how they're made/ designed, safety in salty environments; aerodynamics of aircraft – sustainability through reduced drag; and flight testing and operation of electric aircraft.

Deliverables for this work package include creation of a lecture series on development and operation of hybrid aircraft, completion of student outreach events, and a report from students on chosen research topics.

WP6A: Regulatory

WP6 begins with repositioning of the aircraft from the USA to the ABC islands and concludes at the end of the pilot operations in the islands. It also includes all aviation authority's engagement aspects and Phase 3 planning activities.

This stream of work for the regulatory portion of this work package includes gathering the evidence and performing risk assessments necessary to obtain experimental certificates for our aircraft to fly in Aruba and Curacao, and a permit to fly to be able to fly in Bonaire (Netherlands). It also includes a stream of activity to understand any airworthiness regulation differences, to pave the way for phase 3 and certified commercial flight in Bonaire beyond that, along with broader Phase 3 planning activities.

WP6B: Dutch Caribbean Pilot Operations

Pilot operations comprise repositioning the aircraft from the USA to the ABC Islands, selecting pilots to perform flights between islands, selecting ground crew, flight operations planning and execution, ground operations planning and execution, certification activities (possibly), preparation for interisland commercial operations, and program management.

Deliverables associated with Work Package 6 are the experimental and permit submissions and an FAA-EASA airworthiness study.

1.4. Phase 3 Work Packages

Phase 3 has not yet been approved for planning. This phase would be similar in activities to that performed in Phase 1. In this case, Phase 3 would begin during the back half of Phase 2 to plan in detail the required activities for Phase 3. It would also include delivery of an initial draft for budget planning purposes.

Activities for Phase 3 would also include the following items, and additional tasks may be added out of necessity or by request.

- Continued non-commercial pilot operations with local operators supporting and flying the aircraft in conjunction with Ampaire personnel
- Adding features to the predictive DOC model such as a GUI for increased user friendliness and a better method for exporting results to share with operators and stakeholders
- Continued infrastructure analysis and scale up support
- Ampaire aims to also validate and test the basic Hybrid Caravan training curriculum
- Further curriculum development and continued education activities, maintenance training, and flight training

- Development of a follow up lecture series that presents findings from Phase 2
- Engagement with regional aviation authorities for updates to regulations for commercial electrified aviation flights

1.5. Hybrid Technology Overview

The hybrid powerplant developed by Ampaire combines a Sustainable Aviation Fuel (SAF) compatible engine with an electric motor/generator, inverter power electronics, and battery pack that can be charged on the ground using a portable electric charger and regeneratively charged in flight.

Why not all-electric? Why not hydrogen? Why don't we just use all sustainable aircraft fuel (SAF)?

All-electric Aircraft

The present state of battery technology is the limiting factor preventing all-electric aircraft from becoming a reality today. Though battery efficiency improves at a steady rate, and new cell technologies are in development, battery packs that comprise hundreds to thousands of individual low gravimetric density battery cells are large and heavy. For a Cessna Grand Caravan 208B, on which the Hybrid Caravan is based, most of the cabin would need to be filled with battery packs to provide enough power to fly a standard, practical route of 80 to 160 km (50 to 100 miles). Removing seats or cargo space from the aircraft results in a higher cost-per-mile for the air carrier. Over time, batteries will become lighter and more efficient, but it will take an estimated 10+ years to see enough battery efficiency improvement for more than very low payload, short range operations. Optimally this would be combined with a clean-sheet aircraft design to make all-electric air transport practical, vastly increasing capital expenditure and time to market.

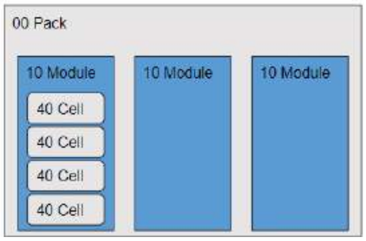

Figure 1: Battery Pack Elements

Ampaire's goal is to add all-electric aircraft to its portfolio when the battery technology improves, and it is practical to do so. The matured electric machines, power electronics, and energy storage systems Ampaire is commercializing for hybrid applications will be leveraged for these future all-electric applications. Even when batteries are at this stage of efficiency, hybrid powertrains will still have their place in larger aircraft, to maximize payload and range.

Hydrogen Power

Hydrogen powered aircraft are a strong future possibility for the industry. Only recently has the technology developed enough to be considered for air transport applications. As it is an emerging technology, it cannot be applied for practical applications today. There are no aircraft powerplants or engines that operate on hydrogen, yet, whereas combustion engines using jet fuels have been around for a long time and are proven and well understood. Hydrogen as a fuel is also not readily available, yet, and the process to create compressed hydrogen for fuel is not efficient or widely available for research and experimentation by OEMs. Extensive testing is also needed in aircraft using hydrogen as fuel to verify safety and efficiency.

Hydrogen also has a volume density challenge requiring nine times the jet fuel volume for gaseous hydrogen storage, and three times the volume for liquid hydrogen. Liquid hydrogen requires the complexity, space, and weight of cryo systems on board. For any significant range applications completely reimagined aircraft designs are likely necessary to accommodate the hydrogen storage.

The generation of "green" hydrogen requires an abundance of green energy, which is not yet utilized or available in most places. As the current method of generating hydrogen for fuel is very inefficient, many in the industry are deciding to use green energy directly in everyday energy applications instead.

The implementation of hydrogen as fuel in the ABC Islands would take significant infrastructural modifications and would not be practical until hydrogen fuel is more readily available, less expensive, and transport aircraft are using it as a fuel source. Whilst hydrogen could eventually be an excellent sustainable solution, it is not a solution for the immediate future.

Sustainable Aviation Fuel

Sustainable aviation fuel (SAF) is a blend of standard aircraft fuel and non-petroleum based, renewable sources such as food waste; fats, grease, and oils; municipal solid waste; alcohols; and yard waste (https://afdc.energy.gov/fuels/sustainable_aviation_fuel.html#:~:text=SAF%20can%20be%20produced%20from,%2Foils%2C%20and%20other%20feedstocks.).

SAF can be used today to significantly reduce carbon emissions in all aircraft that use jet fuels making it a seamless technology transition when commercially ready. However, there are no companies presently mass producing SAF, and availability is limited, which also makes it significantly more expensive than traditional jet fuels.

The ABC Islands airports intend to use SAF and make it available to all air carriers as soon as it is available in typical distribution. Some are considering the manufacture of SAF themselves. Plans are in place and underway to make SAF a normal component of airport operations in the Islands, and SAF will likely be an option for use withing the next few years.

The Hybrid Solution

Ampaire believes that the hybrid approach is the most practical way to achieve reduced carbon emissions in commercial aircraft today by leveraging technologies that are available now. Ampaire has three flying hybrid aircraft that have flown over 23,000 nautical miles. One of which has flown over 3,000 miles without needing to be recharged. While a battery pack, electric motor, and combustion engine burning Jet A aircraft fuel significantly reduces carbon emissions, the solution becomes truly sustainable once SAF is used. Hybrid aircraft propulsion is providing data and a matured supply chain that will help the industry move forward to all-electric aircraft propulsion, and it can make a significant impact now.

Hybrid solutions can be configured to series hybrid-electric or parallel hybrid-electric depending on the aircraft and needs of the air carrier or customer.

A hybrid architecture is defined as series when only one mechanical source of power is driving the propeller (or the wheels), while a parallel architecture has multiple sources of mechanical power. The series hybrid model uses an engine-generator and a battery pack to provide electric power to an electric power unit (EPU), also known as an electric engine, that turns the propeller shaft and propeller.

The advantage of the series hybrid architecture is that it can use many different types and sizes of engines for the engine-generator and different battery options. It is also easily scalable to distributed electric propulsion applications with many EPUs or electric engines. The main drawback comes from the need to have a rectifier to convert the mechanical power from the engine-generator to electrical power. The rectifier adds to overall powertrain volume, weight, and throughput losses so series engine-generator hybrid is less attractive when only driving one or a couple propellers.

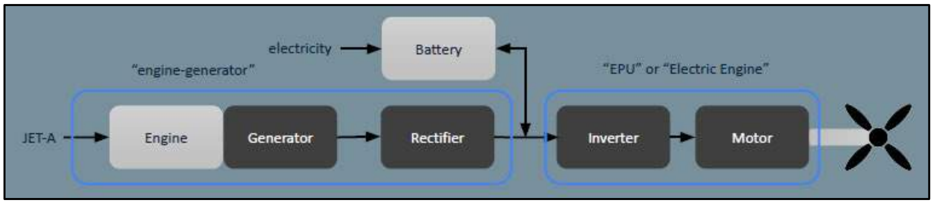

Figure 2 - Series Hybrid Architecture Example

A hybrid architecture is defined as integrated-parallel when the propeller can be driven either by the electric engine (EPU) or by the combustion engine or by both simultaneously. The parallel hybrid model example uses a battery, electric engine (EPU), and a combustion engine. The power from the electric engine (EPU) and the engine are fed into a complex gearbox that turns the propeller shaft.

The advantage of the parallel hybrid architecture is that the combustion engine can be smaller and lighter because the EPU provides the additional maximum power required for aircraft takeoff and climb. Parallel hybrids also have a significant advantage over series hybrids of being able to operate safely on the combustion engine alone in the event of electrical system failure.

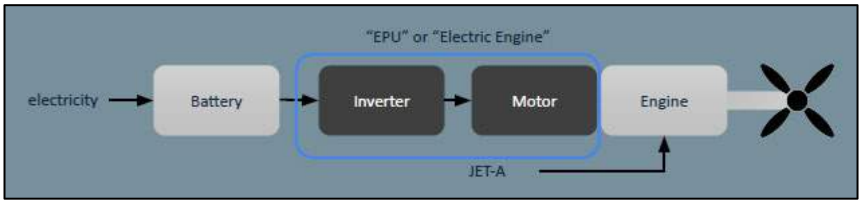

Figure 3 - Parallel Hybrid Architecture Example

The Hybrid Caravan proposed for Phase 2 pilot operations in the ABC Islands has an integrated-parallel powertrain. This system is a combination of both the parallel architecture and the series functionality. It uses the parallel physical combination of the combustion engine and the electric motor directly driving the propeller shaft to gain those redundancies and advantages, then adds the ability to be an engine driven generator for battery charging.

The integrated-parallel Hybrid Caravan is capable of self-recharge and operating without the need to plug in, which is a strong advantage when charging infrastructure is unavailable or where there is insufficient time to charge on the ground. Without the need to recharge on every landing, the integrated parallel system can take advantage of inexpensive, clean grid power where available.

Figure 4 - Ampaire's Hybrid Caravan Prototype Aircraft

The Hybrid Caravan uses a single propeller driven by a SAF-capable engine and electric motor that replace the original turbine engine. The SAF-capable engine and electric motor are supplemented by a battery pack. This design exploits the efficiencies of both engine and electric motors in different phases of flight, optimizing overall performance and maximizing range.

The integrated parallel powertrain used in the Hybrid Caravan is called the AMP Drive™. The powertrain consists of a SAF-capable compression ignition engine with a highly efficient 800V electric powertrain and customized energy storage system (battery pack). The powertrain is currently in the 500-600KW (up to ~800hp) class as a replacement for the most common midsize turboprops, with further capability growth planned to replace even larger turboprops.

Hybrid aircraft offer substantial fuel and operating cost advantages over legacy technologies even using current state-of-the-art batteries, and this advantage will only grow as batteries improve and charging infrastructure spreads to more airports.

2. Route Assessment

This section is associated with Work Package 2. It focuses on assessment of the costs and emissions of air routes between the ABC islands and the operators and stakeholder involved.

The routes assessed have origins and destinations between 40 and 100 nautical miles apart, which are very short distances for aircraft operations. Short routes are challenging for operators since aircraft use large amounts of fuel during takeoff. During short flights, aircraft spend a large percentage of the overall flight time in the takeoff and climb phases of flight, and the overall fuel consumption per passenger mile worsens over time, which can make these routes economically unfeasible for traditional aircraft. The short flights lead to a high number of cycles per day: starting the aircraft, taking off, landing, and shutting it down, which leads to increased maintenance due to wear.

The direct operating cost (DOC) tool from Ampaire was used to investigate the routes between the ABC Islands. This provided an understanding of the operating cost and carbon savings that would result through the implementation of the Hybrid Caravan by comparing hybrid flights to the direct operating costs of a conventional Cessna Caravan. Direct operating costs are always based on a specific mission profile and include fuel cost, electricity cost, maintenance cost, which includes parts and labor, and the battery cost.

2.1. Model Creation and Variables

The model used to predict the direct operating costs utilizes Excel spreadsheets developed by Ampaire for the Hybrid Caravan propulsion system and airframe. The model tracks the performance of the aircraft through multiple flight phases in a mission using inputs such as climb to altitude, cruise speed and desired power output. The fuel usage is taken directly from this performance and the cost of fuel is added to the maintenance model costing. Labor and other contributors such as expected fees to generate a direct operating cost for that flight. During the initial assessment at the beginning of Phase 1, the inputs and routes used were taken from market research using flight tracking services such as FlightAware and flight radar. Some initial discussion with airlines operating on the islands enabled the inputs to align more closely to real routes flown to provide a more accurate assessment of operating costs and emission production. After the initial meeting with each of the operators, a discovery form was sent which contained the necessary information required from each operator to produce more realistic routes.

The model is a mission analysis tool that predicts the performance of the aircraft through all its phases of flight including take-off, climb and cruise based on the inputs from operators on flight distance, altitude, and desired speed, and from the aircraft's power available through the powertrain system. Ampaire currently operates the Hybrid Caravan using the electric propulsion system as an 'electrical boost'. This means it is fully powered during take-off and the initial climb phase up to five minutes of climb then eases off in the cruise phase where it is just the combustion-ignition engine powering the aircraft. This creates better take-off performance and higher rates of climb leading to the aircraft reaching its cruising altitude quicker and decreasing the amount of fuel used in the mission. During a cruise the operator can choose to divert power from the engine to recharge the batteries or to wait to recharge on the ground using a plug-in charger unit.

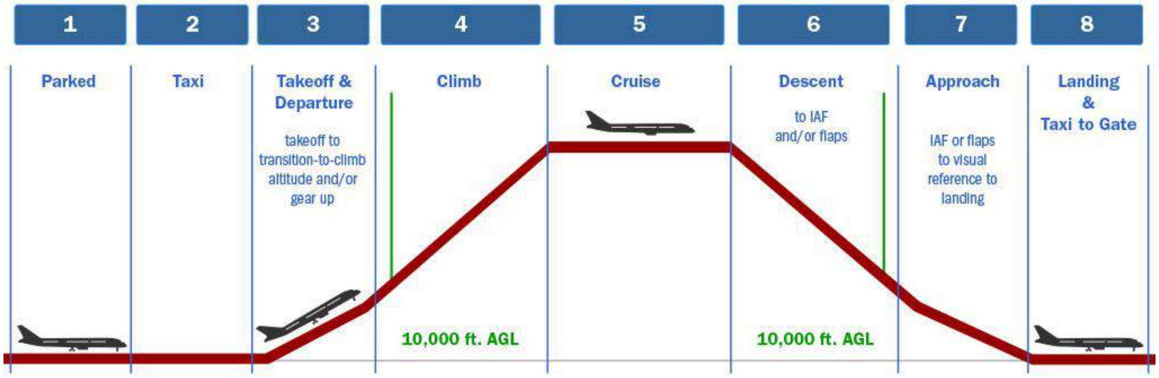

Figure 5 - Phases of Flight Example, https://i.stack.imgur.com/YfgTX.jpg

After the model runs the performance through all flight phases in each route the time taken, and power used to complete each phase of flight and then the total mission is assessed. The fuel used and electricity used is then output. Fuel cost is one of the major contributors to operating cost and so the fuel usage prediction of the model is one of its key attributes. The cost of electricity for recharging and for fuel has been provided by the Energy Transition Initiative [1] and quotes from Curoil, the company that supplies most of the aviation fuel on the three Islands. As no SAF is available on the Islands, costs from online reports have been used. [2][3]

The direct operating costs calculated by the model also include maintenance costs. The model splits up the maintenance costing into five categories: engine maintenance, propeller maintenance, airframe and avionics maintenance, EPU hourly cost addition, and the battery lease cost addition. The replacement and maintenance costs of these systems/ components and the flight hours limit have been calculated by Ampaire, based on data provided by equipment and component suppliers. The maintenance costs differ between the hybrid and baseline versions due to the significantly different propulsion system. For example, the original PT6 turboprop engine in the Caravan counts every start-up as a cycle towards its life while the Amp Drive™ in the Hybrid Caravan counts every flight hour as a cycle towards its limit. For operations in the ABC islands where multiple flights can take place in a single flight hour this means the Amp Drive™ has a longer timed lifespan before an overhaul is required, bringing down costs.

2.2. Considerations for Island-specific Costs

Along with fuel, electricity, and maintenance costs, there are extra costs added to the overall operating costs of the aircraft that are more dependent on the location than the actual physical aircraft. This includes labor fees, FBO fees, and airspace fees. These fees are not variable costs between a baseline and Hybrid Caravan but are a significant percentage of the direct operating cost. Due to the remoteness of the three Islands the supply of trained mechanics, ground crew and pilots are limited compared to more accessible locations, and therefore labor costs are quite high compared to the usual standard. The DC-ANSP manages the airspace around the ABC islands and charges an ATC fee every time an aircraft enters the airspace. This cost is the same for every aircraft leading to smaller aircraft having a larger cost per passenger associated with this. The airports themselves on the Island have their own set of fees for landing which need to be considered. At the airports, depending on size, there is usually an FBO that will provide services such as fueling, parking, and hangaring aircraft. The FBO charges a fee per landing and/ or take-off. For the air ambulance service, currently provided on behalf of FM (which utilizes a Learjet 35), the average service charge at the FBO for take-off and landing is $1,000. It is unclear at this stage the cost for a Hybrid Caravan to make use of the FBO facilities due to its differences in fuel amounts, handling, hangarage size and turnaround time, therefore the price of $1,000 is assumed for all aircraft.

The island-specific costs contribution to the DOC does not change whether the Caravan is a baseline or hybrid type, but that may change in the future due to initiatives from the DCCA. The DCCA is currently considering an incentivization package for sustainable flight in the Islands. The aim is to reduce the costs of sustainable aviation operations, through the reduction of fees such as airport and FBO fees, though it is unclear at this stage whether there would be changes to the ATC fees also. These incentives would further reduce the DOC for the Hybrid Caravan, adding to the commercial attractiveness.

Another goal from the DCCA and the Dutch Ministry is to promote sustainability and aviation knowledge throughout the Islands. Encouraging and inspiring more students to pursue careers in the aviation sector, whether as mechanics, pilots, or in the energy industry to promote renewable energy in the islands, will lead to additional reductions in labor expenses and the cost of renewable energy and SAF in the region.

2.3. Considerations for Ambulance-specific Operations

This section includes initial information for the study of an air ambulance route being carried out by the Hybrid Caravan. This route was specifically included in the Dutch action plan electrical flying for the ABC islands from the Netherlands Airport Consultants (NLR/NACO). This route assessment study is a further exploration into a sustainable air ambulance initiative. There are some differences to operating an air ambulance as opposed to a commercial passenger operation. The interior of the aircraft is different for the ambulance operation, with a different weight distribution. The passenger seats are removed and replaced with room for a stretcher and medical equipment. The weight of the equipment including short box, stretcher, defibrillator, and monitoring instruments weighs approximately 110kg. The crew constitutes a medical doctor, senior nurse, and nurse each weighing approximately 90kg. The patients will have a limitation of 130kg and will be allowed a single accompanying person of maximum 90kg. This additional 600kg when added to the operating empty weight of the aircraft weighs less than a fully furnished passenger aircraft with passengers. With the Hybrid Caravan, there is approximately a 400kg saving of weight with the same fuel amount which will result in a reduced power required to operate a similar mission, resulting in less fuel used and a corresponding lower DOC.

The air ambulance is operated differently to a passenger operation. An air ambulance operation can open up airports to be first in line to land and take-off due to the ability to fly under humanitarian circumstances. There are no medical restrictions regarding speed and steepness of climb for the medical flights, however, if the patient has been injured in a diving accident or has a neurological injury, the ambulance is required to fly at a lower altitude. For this study, the altitude was set at 2000ft as higher altitudes increase the risk of decompression sickness or worsening symptoms of patient.[4] Due to the level of tourism focused on SCUBA and freediving in the ABC Islands, this is an important consideration to analyze for air ambulance operations. The turnaround time is also different for air ambulance operation and typically lasts around 90 minutes compared to the quick turnaround of 20-30 minutes for the small passenger operators. This allows for the patient to be safely transferred off the aircraft and onto the on land medical transport. When the patient is confirmed as safely transferred and any staff changes have completed the air ambulance either returns to base airport or completes another mission. This longer turnaround time allows for the

Hybrid Caravan to be fully recharged on the ground during the turn-around-time, which represents the most cost-effective way of operating the aircraft.

2.4. Results

The route assessments for this study looked at multiple sectors making up the possible routes between the three ABC islands. The sectors looked at are:

- TNCA-TNCB: Aruba to Bonaire
- TNCA-TNCC: Aruba to Curacao
- TNCB-TNCA: Bonaire to Aruba
- TNCB-TNCC: Bonaire to Curacao Direct
- TNCB-TNCC: Bonaire to Curacao Indirect – may be required to not fly over environmentally protected areas in Bonaire.
- TNCC-TNCA: Curacao to Aruba
- TNCC-TNCB: Curacao to Bonaire

For each of the sectors the most efficient altitude based on flight distance was calculated automatically by the model except for the air ambulance studies, where the altitude was set at 2000ft.

The following tables show the performance of the aircraft throughout each sector, the fuel usage, maintenance costs and overall, DOC per seat mile for the Hybrid Caravan. The baseline Caravan aircraft DOC per seat mile for that route is also tabulated and the percentage cost saving is also shown. The Hybrid Caravan performance and costing results are split into methods of charging the Hybrid Caravan:

1. In-flight charging mode: During the cruise phase power is diverted from the propulsion unit to charge batteries. Depending on length of cruise phase the aircraft can fully regain the electricity used during the take-off and climb phase of the mission. Refer to section 3.1 Missions with in-flight charging.
2. No In-flight charging mode: No power is diverted during the cruise phase and all recharging Is completed on the ground via a plug-in method. The aircraft can cruise at a higher speed due to the excess power available. Refer to section 3.2 Missions without in-flight charging.

2.4.1. Missions with In-flight Charging

The following table shows in-flight charging details for each flight route. The table splits up the routes into its total flight distance in nautical miles, the cruising altitude and speed in cruising. The study shows that there is enough power to carry all nine passengers on each the route. Except for the direct routes between Curacao and Bonaire, the batteries can be fully recharged in flight with the diverted power leading to very short turnarounds at the airports. The electricity usage is not so large for the shorter routes that multiple flights can take place before needing a full charge on the ground.

Sector	Distance (nmi)	Cruising Altitude (ft)	Speed (kts)	Passengers	Available Payload (lbs)	Flight Time (min)	Full in-flight charging
TNCA-TNCB	107	7500	134	9	2251	60.9	Yes

TNCA-TNCC	69	6000	134	9	2292	46.4	Yes
TNCB-TNCA	107	7500	134	9	2251	60.9	Yes
TNCB-TNCC Direct	41	5000	134	9	2337	30.4	No
TNCB-TNCC Indirect	80	7000	134	9	2273	53.3	Yes
TNCC-TNCA	69	6000	134	9	2292	46.4	Yes
TNCC-TNCB	41	5000	134	9	2337	30.4	No
Ambulance TNCA-TNCC	68	2000	134	9	2303	40.7	Yes
Ambulance TNCB-TNCC	79	2000	134	9	2120	45.1	Yes

Table 3 - Performance details for each sector assuming in-flight charging

The following table details the actual electricity and fuel usage for each sector. Due to in-flight charging, the electricity cost is not calculated here while fuel cost is. The lower altitude of the air ambulance operations contributes to a reduction in fuel usage, going from 105.7 lbs. to 94.7 lbs. for the TNCA-TNCC route. Maintenance costs are split into powertrain specific maintenance and other systems maintenance. From the results, total DOC savings vary from 18.7 to 31.1% with an average of 25.7%. The savings are more for the air ambulance routes showing that a lower altitude and shorter climb phase helps to maximize savings and that savings are largest for the smallest routes such as the TNCC-TNCB sector.

Sector	Electricity Usage (kWh)	Fuel Burn (lbs)	Fuel Cost	Powertrain Maintenance Cost	Other Maintenance Cost	Total Trip Cost	Hybrid Caravan DOCS per ASM	Baseline Caravan DOCS per ASM	DOC Savings
TNCA-TNCB	18.5	146.5	$134.27	$101.50	$163.18	$398.95	$0.36	$0.47	23.9%
TNCA-TNCC	14.4	105.7	$96.89	$77.30	$124.28	$298.46	$0.41	$0.54	22.6%
TNCB-TNCA	18.5	146.5	$134.27	$101.50	$163.18	$398.95	$0.36	$0.47	23.9%
TNCB-TNCC Direct	11.6	60.3	$55.32	$50.71	$81.53	$190.17	$0.45	$0.65	31.1%
TNCB-TNCC Indirect	17.2	124.3	$113.97	$88.79	$142.74	$345.50	$0.41	$0.51	18.7%
TNCC-TNCA	14.4	105.7	$96.89	$77.30	$124.28	$298.46	$0.41	$0.54	22.6%
TNCC-TNCB	11.6	60.3	$55.32	$50.71	$81.53	$190.17	$0.45	$0.65	31.1%
Ambulance TNCA-TNCC	5.4	94.7	$86.79	$67.85	$109.08	$263.72	$0.37	$0.52	29.2%
Ambulance TNCB-TNCC	2.7	107.4	$98.45	$75.21	$120.91	$294.57	$0.54	$0.76	28.6%

Table 4 - Costing details for each sector assuming in-flight charging

2.4.2. Missions Without In-fight Charging (using Plug-in Charging)

The following table shows the performance details for the routes assuming no power is diverted from the engine to recharge the battery pack in-flight. A variable to note here is that the speed has increased to 142kts as the full continuous power of the engine (without electric boost function) is now used in cruise resulting in a shorter flight time. The electricity usage and recharge time are shown in this table also. The recharge time varies from 23.2 minutes to 37.1 minutes for the passenger routes. This is longer than the aimed 25 minutes turnaround time which could mean in-flight charging is a more desirable choice for passenger commercial operations.

The electricity usage on the ambulance routes is significantly lower than the baseline routes due to the shorter time in climb. Due to the short distances especially in the direct Bonaire to Curacao route the electric boost function could possibly be used in cruise to add speed or reduce the engine output, for time critical operations. This would reduce flight times and fuel used further, but at the detriment of battery life.

Sector	Distance (nmi)	Cruising Altitude (ft)	Speed (kts)	Passenger Number	Available Payload (lbs)	Flight Time (min)	Electricity Usage (kWh)	Recharge Time (min)
TNCA-TNCB	107	7500	142	9	2251	59.3	18.5	37.1
TNCA-TNCC	69	6000	142	9	2292	46.4	14.4	28.8
TNCB-TNCA	107	7500	142	9	2251	59.3	18.5	37.1
TNCB-TNCC Direct	41	5000	142	9	2337	11.6	23.2	23.2
TNCB-TNCC Indirect	80	7000	142	9	2273	53.3	17.2	34.4
TNCC-TNCA	69	6000	142	9	2292	46.4	14.4	28.8
TNCC-TNCB	41	5000	142	9	2337	29.9	11.6	23.2
Ambulance TNCA-TNCC	68	2000	142	9	2303	40.2	5.4	10.7
Ambulance TNCB-TNCC	79	2000	142	9	2120	44.9	2.7	5.3

Table 5 - Performance details for each sector assuming plug in charging

The results from the cost analysis of each sector shows that plug in charging follows the same trend as in-flight charging with shorter routes and climb phases showing more cost saving. The DOC savings vary from 18.3 to 32.9% here with an average of 26.6% slightly more savings than in-flight charging. This gives some options to operators to devise their own configurations for what best suits their operating goals.

The following table shows a breakdown of the cost of each route. These numbers may change if fees are increased in the future.

Sector	Recharge Cost	Fuel Burn (lbs)	Fuel Cost	Powertrain Maintain Cost	Other Maintain Costs	Total Trip Costs	Hybrid Caravan DOC per ASM	Baseline Caravan DOC per ASM	DOC Savings
TNCA-TNCB	$1.76	141.6	$129.81	$98.83	$158.90	$389.30	$0.35	$0.47	25.7%
TNCA-TNCC	$1.37	105.7	$96.89	$77.30	$124.28	$299.83	$0.42	$0.54	22.3%
TNCB-TNCA	$1.76	141.6	$129.81	$98.83	$158.90	$389.30	$0.35	$0.47	25.7%
TNCB-TNCC Direct	$1.10	58.9	$53.98	$49.89	$80.22	$185.20	$0.44	$0.65	32.9%
TNCB-TNCC Indirect	$1.63	124.3	$113.97	$88.78	$142.74	$347.13	$0.41	$0.51	18.3%
TNCC-TNCA	$1.37	105.7	$96.89	$77.30	$124.28	$299.83	$0.42	$0.54	22.3%
TNCC-TNCB	$1.10	58.9	$53.98	$49.89	$80.22	$185.20	$0.44	$0.65	32.9%
Ambulance TNCA-TNCC	$0.51	93.3	$85.56	$67.08	$107.84	$260.99	$0.37	$0.52	30.0%
Ambulance TNCB-TNCC	$0.25	106.7	$97.84	$74.82	$120.30	$293.21	$0.54	$0.76	28.9%

Table 6 - Costing details for each sector assuming plug-in charging

2.4.3. Fuel and Emissions Savings (In-flight Charging Specific)

The following table goes into more detail about fuel savings between the baseline and Hybrid Caravan based on the specific fuel types used. The amount of fuel savings as a percentage varies from 40 to 51% with each sector assuming JetA vs JetA and the costings change depending on the fuel type. The first cost comparison is a like-to-like replacement with the Caravan using Jet A (rather than SAF), which would occur if the Hybrid Caravan was to be deployed soon. In the second comparison, the new aircraft is deployed at the same point in time in which SAF is introduced on the Islands. The comparison is between a Jet-A fueled standard Caravan and a SAF fueled Hybrid Caravan. The third comparison shows the fuel and emissions savings when the Hybrid Caravan were to be introduced after SAF is readily available and therefore the comparison is between a SAF fueled standard Caravan and a SAF fueled Hybrid Caravan. Due to the high cost of SAF currently, when a comparison is performed between using Jet-A on a standard Caravan and using SAF on the Hybrid Caravan then the cost benefit is positive, but not as significant as for the like-to-like comparisons.

Sector	Fuel Savings (GAL)	Fuel Savings (%)	Fuel Savings Jet A- Jet A ($)	Fuel Savings Jet A-SAF ($)	Fuel Savings SAF - SAF ($)
TNCA-TNCB	14	40%	$87.1	$9.9	$138.9
TNCA-TNCC	12	43%	$72.7	$15.1	$116.0
TNCB-TNCA	14	40%	$87.1	$9.9	$138.9
TNCB-TNCC Direct	9	51%	$55.5	$23.4	$88.5
TNCB-TNCC Indirect	13	42%	$80.9	$13.1	$129.0
TNCC-TNCA	12	43%	$72.7	$15.1	$116.0
TNCC-TNCB	9	51%	$55.5	$23.4	$88.5
Ambulance TNCA-TNCC	10	42%	$61.6	$10.7	$98.3
Ambulance TNCB-TNCC	11	40%	$66.4	$8.2	$105.8

Table 7 - Fuel savings for the in-flight charging specific configuration

This table shows the emissions savings for each sector again with the three different fuel type comparisons. The carbon emissions weight is kilograms is calculated by the fuel usage against online sources for carbon emissions (kg/gal)[5]. These emissions quoted are the cardon dioxide equivalent value which includes the various other greenhouse gases and not just carbon dioxide.[6] The emissions saved for like for like replacement are between 40% and 51% whilst the emissions savings for SAF replaces Jet A lie around 88%. It is most likely that the aircraft gets deployed in the ABC islands before SAF is readily available in the region so the JetA-JetA, like for like results are the most realistic predictions for the near future.

Sector	Fuel Savings (GAL)	Fuel Savings (%)	Fuel Savings Jet A- Jet A ($)	Fuel Savings Jet A-SAF ($)	Fuel Savings SAF - SAF ($)
TNCA-TNCB	14	40%	$87.10	$9.90	$138.90
TNCA-TNCC	12	43%	$72.70	$15.10	$116.00
TNCB-TNCA	14	40%	$87.10	$9.90	$138.90
TNCB-TNCC Direct	9	51%	$55.50	$23.40	$88.50
TNCB-TNCC Indirect	13	42%	$80.90	$13.10	$129.00
TNCC-TNCA	12	43%	$72.70	$15.10	$116.00
TNCC-TNCB	9	51%	$55.50	$23.40	$88.50
Ambulance TNCA-TNCC	10	42%	$61.60	$10.70	$98.30
Ambulance TNCB-TNCC	11	40%	$66.40	$8.20	$105.80

Table 8 - Fuel savings for the in-flight charging specific configuration

2.4.4. Results for Air Ambulance Operations

The air ambulance on the Islands is currently a Learjet 35 with a transition to a Learjet 45 towards the end of 2024. At this stage of the route assessments for phase 1 there is no direct mission comparison between the Hybrid Caravan and the Learjets to show specific fuel savings and cost savings at each route. However, there is average DOCs for each Learjet found from online sources that can be compared to the average DOC for the Hybrid Caravan. The Learjet 35 has an average DOC of $2400 an hour and the 45 has an average DOC of $2120 per hour. This is compared to the average DOC for the Hybrid Caravan of $350- $400 per hour. Therefore, the Hybrid Caravan has a DOC of only 83% reduction of the Learjet 35 [7] and 81%

the Learjet 45 [8]. Note this does not include the Island specific costs for the fuel, electricity usage and maintenance costs, however the Island specific costs of labor, ATS and landing fees will be similar for both Caravan and Learjet with the FBO fees being slightly higher for the Learjet.

A minor compromise for this extreme cost reduction between the Learjets and the Hybrid Caravan is the cruise speed. The Learjet currently cruises for its Island missions at 190kts while the Hybrid Caravan will cruise at 160kts or at 142kts in its most cost optimal configuration, utilizing ICE power only. While this speed difference could be significant over long distances for an air ambulance mission, over the distances in the ABC islands this will only result in an increased mission time of up to 8 minutes for the longest route and 3 minutes for the shortest. Given the aforementioned time on the ground of 90 minutes for the air ambulance, this increase in time is not so significant as to negatively impact missions.

The short distance operations and average DOCs would suggest that a Hybrid Caravan would be the economical choice for an air ambulance operation in the Islands.

2.5. Plan for Future Phases and Studies

Phase 1 used the current Ampaire performance model to predict costing for each route. There are some assumptions and aspects of the model that can be improved with higher fidelity for future route assessments, with additional development time.

During future project phases, more detailed discussions will be held with multiple airlines operating in the islands. Ampaire's aim is to have a complete list of expected outputs from the model that answers all operating questions the airlines have for flying a Hybrid Caravan from a performance and costing POV. Ampaire would aim to work with these operators to obtain missions and routes that exactly match what is currently being flown including all island specific costs such as airspace navigation fees and landing costs to analyses the exact operating costs for the Hybrid Caravan. After analyzing what is currently flown, the model will be used to develop new routes and daily flight schedules that fully leverage the technology in the hybrid system to maximize the benefit to the operators. Discussions with maintenance organizations and airports will also contribute to obtaining an accurate DOC for each flight by updating Ampaire's estimations of maintenance costs in materials and labor. Finally, Ampaire will implement details of the incentivization plan created by the DCCA task force within the model, as the plan is developed. This will allow the taskforce and other stakeholders to understand how these incentives translate into real world affordability of air travel for local people.

This report only covers basic passenger operations and air ambulance operations. Other operations that may also be analyzed for their performance and DOC with the Hybrid Caravan could include flight training patterns, surveillance for environmental mapping along the coast or sky diving operations on the island. Further expansion into the route analysis studies could also involve some routes on the 3S islands, as desired.

Another future study could include expanding the model to predict a more accurate emissions output with a breakdown into different byproducts other than CO_2.

A very useful addition to the model is proposed to create models for the current aircraft used by the operators, to allow for a direct comparison for the operators, rather than a comparison against the baseline Caravan aircraft. This will enable a more direct and relevant comparison of performance, cost, and emissions. Basic information on the current aircraft is available but a closer relationship with the operators would be required to have the necessary information for these studies.

2.6. Conclusions

In conclusion the DOC savings between operating a baseline Caravan or operating a Hybrid Caravan, flying on typical passenger, cargo, and air ambulance routes within the ABC islands are significant, with an average reduction in DOC of 25.6%. These very attractive commercial benefits are combined with equally impressive environmental benefits of an average reduction in CO_2 equivalent of 43.5% using JetA and 88.7% using SAF. The upcoming sustainable aviation incentivization package being created by the DCCA is anticipated to provide further commercial benefits and will make sustainable flying even more attractive to operators on the island, which will translate to reduced ticket prices for passengers in the region.

While there are some improvements to the input data identified for the model to help with accuracy, the current stage of prediction has shown savings along all routes for passenger operations are consistent with expectations for these types of operations. This study has also brought forward the idea of a successful and sustainable air ambulance operation in the islands. Future studies would aim to assess the SSS Islands and even broader operations including cargo operations to explore the extent that the islands might benefit from renewable aviation.

2.7. Route Assessment References

Contacts and authorities for route assessments

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3. Infrastructure

This section is associated with Work Package 3. For this study, Ampaire defined the basic infrastructure needed to conduct pilot operations in the Dutch ABC Islands. Through in-person visits, interviews, and surveys, each island's airport was assessed and conclusions drawn about present and future readiness.

3.1. Basic Operating Needs

Caravan operations in the ABC Islands. Each airport was evaluated for its ability to currently support each item, and information was collected to determine how much effort would be required to allow pilot operations to occur.

- Airport electrical grid ability to support a 30kW electrical charger
- Availability of 480V, 63A (minimum), AC 3-phase power in a hangar or accessible location for charger operation; refer to the subsection for charger details
- Availability of SAF (preferred, but JetA can be used)
- Presence of a hangar to accommodate Hybrid Caravan housing, charging, tools and equipment storage, office space, and aircraft maintenance
- Resident FAA-certified A&P IA
- Existing support equipment for a Cessna Grand Caravan (tow vehicle, jacks, etc.)
- Availability of liquid consumables (fuel, oil, hydraulic fluid, lubricants, etc.) to support a Cessna Grand Caravan
- Flight operation restrictions that may inhibit pilot operations

3.2. Queen Beatrix International Airport, Aruba

This airport has a hangar identified that can be used as a base of operations for the Hybrid Caravan pilot program. The hangar already supports high voltage aircraft charging capability and requires only a small upgrade at the electrical connection point to accommodate the Hybrid Caravan's charger. Aruba's airport is currently supporting demonstration flights of Pipistrel electric aircraft, allowing this program to leverage existing enthusiasm for electrified aircraft and infrastructure to support them.

3.3. Flamingo International Airport, Bonaire

Some updates to the Bonaire airport infrastructure are required to support Hybrid Caravan pilot operations. Two new hangars are being built with the intention of supporting electrified aircraft. A temporary hangar is being prepared to support several electric aircraft activities: Pipistrel demonstration flights, flight school assets, and electric aircraft and aviation development while the airport is under construction upgrades, and for future electric aircraft activities. An area close to the existing general aviation apron is being cleared and paved with concrete to expand capability. The airport is also preparing the area for connection to the airport electrical grid where charging electrified ground support and aircraft can occur.

One temporary hangar being considered to support pilot operations is the Sprung Armadillo Door model. Additionally, there is a plan for a new cat-B platform with several building lots available for private or airport-owned hangars and other airport facilities near the ATC tower. Construction of the platform is expected in 2025.

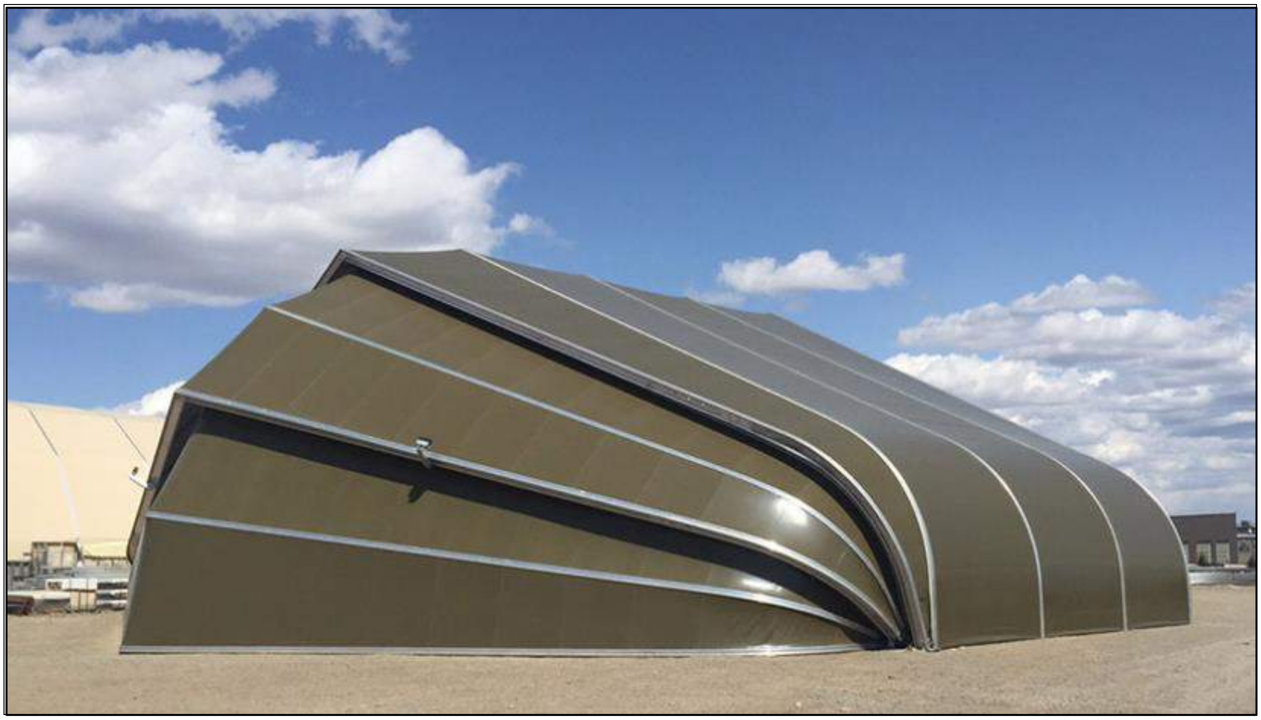

Figure 6 - Sprung Temporary Hangar, Armadillo Model

The airport is upgrading its electrical grid, heading toward its goal of 80% renewable energy. In 2023, twelve 900kW wind turbines were added provide a portion of the island's electricity. The existing airport power grid supplies 110V AC single phase and 220V AC 3-phase electrical power. The island has a 22MW peak demand. Battery storage is 14MWh with a 14MW inverter capacity. The airport uses three 250kW transformers. As of September 2023, a new 6MW solar park, part of the WEB electricity company, went online. This capacity is more than adequate to support Hybrid Caravan charging needs and those of the E-Flight Academy (https://www.eflight.nl/) with their intention of operating a flight school at Bonaire's airport.

In summary, some hangar and electrical upgrades are needed to support Hybrid Caravan pilot operations, but Bonaire airport is well on its way to accomplishing them prior to the anticipated start of pilot operations.

3.4. Hato Curaçao International Airport, Curaçao

The airport at Curaçao is moderately developed with several hangars that could support Hybrid Caravan pilot operations. The airport is leased to the operator on a 30-year contract that expires in 2033. Existing hangars do not have doors, therefore, storage of charging equipment, tool chests, and other assets could not be secured, and therefore different hangar options would be needed to support pilot operations. Four new hangars are planned that should be able to accommodate the needs of the Hybrid Caravan and support equipment.

Existing hangars have 3-phase high voltage available but would require some upgrade to accommodate the 30kW charger required for the Hybrid Caravan.

3.5. Infrastructure Conclusion

The existing and planned infrastructure at the Aruba and Bonaire airports is adequate to support Hybrid Caravan pilot operations as a base of operations. Aruba's airport can support as a base of operations today. For pilot operations, all airports are capable of supporting aircraft turnaround with fuel and personnel should the Hybrid Caravan land there, but not all airports can support charging needs. Some additional study would be required and possibly some infrastructure upgrades made before pilot operations in the ABC Islands could commence.

3.6. Infrastructure References

Contacts and authorities for infrastructure

Persoonsgegevens
Persoonsgegevens
Persoonsgegevens
[redacted]

Websites and documents for infrastructure

1. In-person and email questions with airport authorities
2. CV0Z-DOC-0040002, Dutch Caribbean Electric Aviation Initiative, Discovery and Informational Interview Forms, completed by airport authorities
3. ContourGlobal; https://www.contourglobal.com/asset/bonaire
4. Water-en Energiebedrijf Bonaire (WEB); https://www.webbonaire.com/about-us/?lang=en

4. Logistics for Phase 2 Aircraft Transport

This section provides recommendations for repositioning the Hybrid Caravan to the ABC Islands. Several options were considered including disassembling the aircraft and shipping it to the Islands in shipping containers, having Ampaire's test pilots fly the aircraft from Camarillo, California, USA to the ABC Islands, or hire a professional aircraft ferrying company to reposition the aircraft. Ampaire has first-hand experience with disassembling and shipping aircraft to other countries and flying the hybrid aircraft long distances. Taking this experience into consideration, our conclusion is that hiring a professional aircraft ferrying service to reposition the Hybrid Caravan from Camarillo, California, USA to Aruba is the best option. The following sections describe this rationale.

4.1. Cargo Container Shipping Option

This option is the most expensive, takes the longest amount of time to accomplish, and increases the risk of damage to the aircraft. These were the primary reasons the cargo container shipping option was not considered viable for this project.

In Ampaire's experience, there is a 33% chance of significantly damaging the aircraft during shipment. This risk percentage is based on Ampaire's experience shipping hybrid aircraft to and from the U.K. and from Alaska to California. Even using extreme care during packing, the cargo container can experience handling issues or tie down straps can fail. If damage occurs to the aircraft during shipment, replacement parts often must be ordered or significant repairs performed, causing a delay in program schedule.

Modern challenges in the shipping industry also deterred Ampaire from choosing this option. Currently, the drought in South America is causing shipping delays through the Panama Canal that could impact the duration of Hybrid Caravan shipment if not resolved in the next year.

It should also be noted that disassembling an aircraft significantly increases the risk of damaging the aircraft's systems or components, furthering the risk of program delay.

The following table describes a summary of the estimates Ampaire collected for this option. The one-way estimate is provided should a reason arise to permanently station the aircraft at one of the Island airports.

Factor	One-way Estimate	Round-trip Estimate
Duration	2 to 3 months	4 to 6 months
Cost	$86,000 to $92,500 USD	$172,000 to $185,000 USD

Table 9 - Cargo Container Shipping Option for Hybrid Caravan

4.2. Self-repositioning

This option would utilize one of Ampaire's test pilots and Ampaire's project management staff to plan and coordinate the flight from California, USA to Aruba. The advantage of this option is that Ampaire's test pilot is already familiar with the novel technology and unique instruments of the Hybrid Caravan.

The disadvantage of this option is that Ampaire is not an expert in international aircraft relocation. There are many complexities to consider when flying an aircraft through many different countries such as customs, open water requirements, preferred airports for maintenance should unscheduled maintenance be required, and airworthiness approval requirements for various countries.

While Ampaire personnel could perform the research necessary to safely reposition the aircraft and bring in experts to help, this activity would be time and resource intensive.

The following table describes a summary of the estimates Ampaire collected for this option. The one-way estimate is provided should a reason arise to permanently station the aircraft at one of the Island airports.

Factor	One-way Estimate	Round-trip Estimate
Duration	4 to 6 weeks	8 to 12 weeks
Cost	$78,000 to $88,000 USD	$156,000 to $176,000 USD

Table 10 - Self-repositioning Option for Hybrid Caravan

4.3. Professional Aircraft Delivery

This option would entail hiring a company who specializes in repositioning aircraft internationally and training the ferry pilot on the Hybrid Caravan's novel technology and unique instruments. This option is the least expensive, most flexible, and the fastest.

The aircraft delivery company's ferry pilot would spend 10 to 20 flight hours with Ampaire's test pilot to develop proficiency with the Hybrid Caravan and satisfy insurance requirements. How quickly this familiarization training can be accomplished depends on pilot availability, weather, and aircraft availability.

The aircraft delivery company is already familiar with the complexities of reposition flying an aircraft internationally, and is already familiar with the airspace regulations, customs requirements, and airfields that can accommodate unscheduled maintenance. They would analyze and present route options, how long the repositioning would take, and the risks involved, allowing Ampaire to make an informed decision. The flight from California to Aruba would take approximately one week, depending on weather conditions, crew rest requirements, and unscheduled maintenance.

Figure 7 - Hybrid Caravan Reposition Flight Route Example

The following table describes a summary of the estimates Ampaire collected for this option. The one-way estimate is provided should a reason arise to permanently station the aircraft at one of the Island airports. Note that the Round-Trip Estimate is not doubled. The one-way estimate includes pilot training time. Pilot training does not need to be repeated for the return trip.

Factor	**One-way Estimate**	**Round-trip Estimate**
Duration	2 to 4 weeks	3 to 5 weeks
Cost	$30,000 to $60,000 USD	$60,000 to $120,000 USD

Table 11 - Professional Aircraft Delivery Option for Hybrid Caravan

4.4. Decision

Due to the complexity of international flights, Ampaire intends to hire an experienced aircraft delivery company and their pilots to fly the Hybrid Caravan from its home base in California, USA to Aruba. The company flying the aircraft will have familiarity repositioning turboprop aircraft internationally and will assure that all documentation and airspace requirements are complied with. It is estimated to take 5 to 6 flight days to reposition the aircraft.

After the Hybrid Caravan arrives in Aruba, the A&P IA lead mechanic will perform a thorough inspection and make any necessary repairs or adjustments to assure the aircraft is ready to perform pilot operations.

4.5. Logistics for Phase 2 References

Contacts and authorities for logistics for Phase 2 aircraft transport

None.

Websites and documents for logistics for Phase 2 aircraft transport

1. Advise Customs (U.S.) ADCUS program information; https://www.faa.gov/air_traffic/publications/atpubs/fs_html/chap6_section_2.html
2. DC-ANSP, electronic aeronautical information publication (eAIP); https://dc-ansp.org/eAIS/eAIP-Publications/2023-04-20/html/index-en-GB.html
3. FAA International Flight Information; https://www.faa.gov/pilots/intl
4. FCC requirements for PIC radiotelephone operators permit; (spacing intentional) https://www.aopa.org/travel/international-travel/aircraft-radio-station-licenses-and-pilot-radio-operator-certificates
5. ICAO Convention on International Civil Aviation, Article 29; https://www.icao.int/publications/documents/7300_orig.pdf
6. ICAO flight planning (video); https://www.youtube.com/watch?v=O47m7kILYnc
7. IASA - International Aviation Safety Assessment Program; https://www.faa.gov/about/initiatives/iasa

5. Training and Maintenance

This section aligns with Work Package 5. It describes the unique needs of the technicians working on the Hybrid Caravan and its electric propulsion system (EPS) for flight demonstrations in the ABC Islands. The novel hybrid and electric propulsion technology requires the creation of additional training materials for maintenance and servicing the aircraft. To increase technology awareness and competency in the ABC islands, Ampaire identified some areas to provide education into the technology for both secondary and tertiary level students. Also considered is the additional pilot training required for flying an electric hybrid aircraft with a focus on flight simulators.

Ampaire, in collaboration with the Dutch Ministry, have identified three objectives for training that will deliver extremely valuable output to the Dutch Ministry and stakeholders on the Dutch Caribbean islands.

1. Bring broader knowledge of technical and specialized sustainability education to the islands
2. Develop a specialist knowledge into electric aviation maintenance and servicing.
3. Develop pilot training for the Hybrid Caravan and inspire the next generation of pilots in the Islands

5.1. Maintenance and Servicing Training

Due to the replacement of the standard engine in the Cessna Caravan, with Ampaire's proprietary hybrid-electric propulsion system, current licensed mechanics who can work on the baseline Caravan do not have the necessary training to be able to maintain and sign off any maintenance activities carried out on the Hybrid Caravan. This document covers the steps Ampaire is undertaking to create the necessary training materials and validation of materials to ensure students and currently licensed technicians can maintain the Hybrid Caravan.

5.1.1. Current Aviation Maintenance Training Curriculum and Licensing

To become a licensed technician to maintain aircraft there are two major certification bodies that provide the regulations for training: FAA for America and EASA for Europe.

Under the FAA, an aircraft mechanic is classed as an A&P (airframe and powerplant) mechanic. To become an A&P there are two education routes. The first is to attend an AMT (aviation maintenance technician) school which on average takes two years to complete the course program. To pass and become licensed, the student must pass written, oral, and practical exams. The second route is to become an apprentice and work for 30 months. After this, the mechanic candidate must take the same exams as route one. After becoming an A&P, the student has the option to have further training in avionics electronic equipment to obtain an avionics technician license.

To be licensed to maintain a conventional propulsion aircraft under EASA rules, a technician must undertake specific modules that satisfy theory and practical elements. EASA has two parts involved with training an aircraft technician. EASA Part-66 constitutes the regulatory framework overseeing a standardized European aircraft maintenance license acknowledged across all EASA member states. The second part, EASA Part-147 prescribes the regulations governing a Maintenance Training Organization, which is accountable for providing either Basic or Type Training for Part 66 Engineers. This involves a split of two thirds theory lessons and exams and one third of practical experience. The main types of licenses a technician can obtain is an A, B1 and B2 license. This type of training is considered the basic license training, but a technician can also undertake some supplemental type training if required to maintain specific aircraft types.

A License: An A licensed mechanic can perform minor line maintenance and simple repair of defects. They are not licensed for full heavy maintenance.

B1 License: A B1 licensed technician is a step above an A licensed and can perform maintenance on aircraft structures, powerplant, mechanical and electrical systems. They can perform maintenance on avionics systems that only require simple tests to prove serviceable and require little to no troubleshooting. A B1 license is split into further categories whereby a B1.1 licensed technician works on turbine aircraft and a B1.2 on piston aircraft. There is also the option for a B1.3 and B1.4 which focuses on helicopters over fixed wing aircraft.

B2 License: A B2 licensed technician can perform maintenance on avionic and electrical systems. They can perform maintenance on powerplant and mechanical systems requiring only simple test and minor scheduled line maintenance and simple defect rectification.

5.1.2. Maintenance Colleges in the ABC Islands and Mainland Netherlands

Aircraft technicians are trained through aviation maintenance colleges and schools. These colleges have a set of standards necessary to be able to pass students as fully EASA licensed technicians based on the level of theory and practical experience they can offer. The colleges can offer the basic license training under EASA regulation or can also offer type training for a specific aircraft type. Other companies, such as KLM's MRO, can aid in the creation of curriculum without being a training center, but they have partnerships with aviation colleges to carry out the curriculum.

Ampaire met with two training colleges in person as well as members of the maintenance training department of KLM. In Bonaire, there is one maintenance school, AMTS Bonaire, that trains students from all three ABC Islands in aircraft maintenance. They are the only school in the islands to provide this curriculum. Ampaire met with the college to arrange a relationship where the instructors and students would test and provide feedback on curriculum developed by Ampaire for the Hybrid Caravan. Ampaire also visited ACM 66 Maastricht in the Netherlands to discuss support for the training program. This college is on a larger scale than the Bonaire school and has already begun to create written theory on electric propulsion systems and battery systems for aircraft. The instructors at this college created training for Pipistrel's electric aircraft, one of the first maintenance training programs for an electric aircraft.

5.1.3. Electrified Aviation Maintenance Training

While current training curriculum allows for technicians to maintain conventional propulsion systems, such as turboprop and piston engines, there is no official EASA basic license curriculum in place to train technicians to maintain an electric propulsion systema and battery energy storage system. The basic FAA and EASA training does cover some electrical fundamentals in its standard curriculum, but neither covers the high voltage requirements of electric propulsion.

EASA is currently developing the acceptable means of compliance that a curriculum must meet to certify technicians on electric and hydrogen aircraft. KLM is part of a working group with other large airlines to advise EASA on this development. Ampaire is currently working with KLM and various sustainable aviation companies at a secondary level to advise on necessary content and structure to the new curriculum. There have been two notices of proposed amendments created: NPA 2020-12 and NPA 2021-15, with a 2023 update in progress.

These outline changes to the curriculum intend to support electric and hydrogen aviation through necessary theory, estimated hours of study, and practical experience. One option being discussed within the working parties and EASA is to have a separate module which covers all electric, hybrid electric and hydrogen aviation. A student can take this module instead of the piston and turbine modules to become a “B1E” licensed technician. It could also be possible for current licensed technicians to take this module separately to qualify to maintain both conventional and electric propulsion systems.

During the next phase of this project, Ampaire plans to test and validate the curriculum has been created by utilizing the students at AMTS Bonaire during pilot operations. This will validate the effectiveness of training and feedback improvements. Any feedback given will be used in creating the next drafts of the training materials.

5.1.4. Type Maintenance Training for Hybrid Caravan

The creation of a sustainable aviation module for part 147 and 66 curriculum is a time-consuming project with the first official training being released in a few years’ time after approval and testing. Ampaire can create a specific type training for the Hybrid Caravan that a current, licensed technician can undertake to maintain the aircraft. This type training would follow a similar structure to other type training, taking approximately three weeks with a 66% theory 33% practical split. Depending on how the Hybrid Caravan is certified, and how the EASA regulations for electrified aircraft are structured, a technician may be required to pass a theory and practical exam at the end of the type training before being qualified.

Due to the Hybrid Caravan architecture containing components such as battery modules and electric motors that will be classed as non-repairable by a technician, Ampaire can argue that the complexity of the maintainable systems is not large enough to warrant requiring an exam. The hybrid-electric propulsion system equipment will be replaceable by the technician completing the type training, but specific shop repair and maintenance of this equipment will be carried out by Ampaire and/or their approved maintenance organizations.

In Phase 2, Ampaire will work with either KLM or ACM 66 Maastricht to develop type training for the Hybrid Caravan. They will advise on which materials are necessary to develop sufficient type training and how to properly structure the course. The type training materials will be created through data taken from the current documentation and manuals of the Hybrid Caravan which are under development for the STC. The first draft will then be validated through instructors from KLM or AMC 66.

5.2. Required Training Documents

Training data will need to be pulled from specific documents and manuals. The supplemental aircraft maintenance manual and structural repair manual that is created for the Hybrid Caravan certification process will contain the necessary information. Diagrams, drawings of the structures in the airframe, and propulsion system data are provided in the final STC data package that this program will draw from. The pilot operating handbook will contain the start-up and shut down procedures that technicians will need to properly troubleshoot issues with the avionics and propulsion system and will also include the pre-flight checklists used by technicians and pilots. Technicians will also need access to the updated illustrated parts manual which will include the information on all new components with drawings of their installation. Detailed wiring and architecture diagrams will also be necessary to aid in training to repair replace and troubleshoot the electrical and avionics systems of the Hybrid Caravan.

5.3. Airport Personnel Training

Pilot operations in the ABC Islands require training focused on the unique servicing and ground handling requirements of the Hybrid Caravan. While the aircraft can be towed and receive fuel like a standard aircraft, operating the charger for the electrified propulsion system requires hands-on orientation and practice.

Additionally, ground emergency procedures, such as properly handling battery fires, is required, though this situation is highly unlikely. Each airport fire station will require basic information about the aircraft's unique systems. Ampaire will provide specifics, such as the amount of water needed, what type of PPE is recommended, and what areas to specifically avoid for personnel safety. Training will also cover how to inspect the aircraft and battery pack after an unintended collision with terrain.

5.4. Pilot Training

Pilot training is also a requirement for a successful pilot program in the ABC Islands due to the additional instruments and controls for the hybrid-electric system. There will be differences in cockpit display, throttle controls, and systems that will require pilots to undergo cockpit orientation and flight training before flying the Hybrid Caravan. Part of training will require supervised flying hours and simulator time.

Ampaire is developing a Hybrid Caravan flight simulator. The first iteration will be a desktop computer flight simulation apparatus that provides the unique instruments and controls. Practice with this simulator provides procedural proficiency and the "muscle memory" that pilots rely on for safe flying during periods of high workload. A flight simulator with increasing levels of functionality may result after the assessment of the desktop simulator.

Ampaire intends to create a simulator during Phase 2 in collaboration with a university that will draw from the current aircraft models and add the necessary flight physics and dynamics to operate a fully flyable virtual Hybrid Caravan. Ampaire intends to partner with a university with teams experienced in creating aircraft simulators and who have already produced a flight simulator hardware.

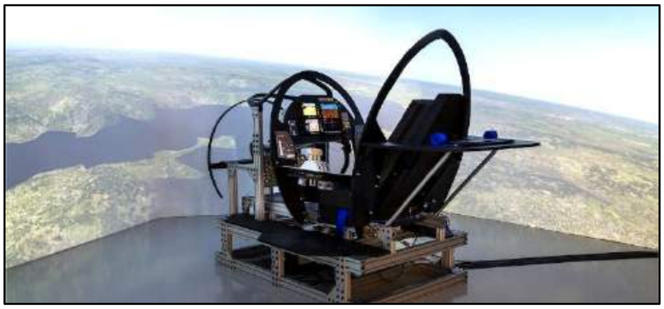

Figure 8 - Portable Flight Simulator

An additional option for Phase 1 and Phase 2 is to supply electrified aircraft pilot familiarization training at Ampaire's facility in the U.S. where select ABC Islands-based pilots can operate one of the Ampaire's fleet of hybrid-electric Cessna 337s.

5.5. Education and Outreach Opportunities

Ampaire aims to make a lasting positive impact for future generations in the ABC Islands. Outside of maintaining and piloting aircraft, there are multiple sectors working to make sustainable aviation a reality including infrastructure, energy generation, airport operations, battery chemists, marketing, academia, etc. In order to enable a sustainable aviation ecosystem in the Islands, it is necessary to train residents in all these sectors and more. Ampaire plans at a secondary level as well as a university level to get people excited and informed on ways to support sustainable aviation.

Ampaire visited a secondary school on Bonaire and the University of Curacao to speak to students and teachers about sustainable aviation and how the ABC Islands has the potential to be a hub for the sector. After speaking to the students and teachers, Ampaire has identified three activity streams to bring the knowledge of sustainable aviation to the ABC islands and mainland Netherlands:

Student led projects: Possibility of sponsoring small student studies into noise abatement and acoustic measurement, renewable energy infrastructure for charging etc.

Competitions for students: Set up a practical project such as development of a UAV to be designed and flown by university student teams over the period of the pilot operations. The level of difficulty can be scaled to a one-day activity for secondary students: plug and play drone or RC aircraft.

Lecture series: Hosted at Curaçao university or base island university with video streaming to others, associated with engineering professional body –KIVI, 5-part series covering flight demonstrations or making sustainable flight possible. Current planned topics for the series include:

- Infrastructure requirements for electric aviation,
- Electric powertrains – theory, operation, testing,
- Batteries – how they're made/ designed, safety in salty environments,
- Aerodynamics of aircraft – sustainability through reduced drag,
- Flight testing and operation of electric aircraft

Ampaire has also discussed with TU Delft the plan for sponsoring a student project into noise measurement of the hybrid aircraft operating in the islands. The initial discussion in this phase have involved deciding that a master's is the correct level for the project and outlining the scope and goals for a noise measurement project.

Phase 2 entails the initiation of efforts to facilitate accessible education and training opportunities on Islands, thereby mitigating the phenomenon of "brain drain," where young people move away to pursue studies and careers aligned with their interests and abilities. Preventing this phenomenon will be achieved through the provision of education within the island locale, obviating the necessity for students to seek education elsewhere. Additionally, measures will be implemented to incentivize their return to the islands after their university studies, thereby encouraging their participation in the dynamic and compelling projects underway.

5.6. Bringing New Skills to the Community

As part of the pilot program, Ampaire recognizes the importance of involving the Islands community to ensure a successful project and to prepare the ecosystem for the transition to sustainable aviation. This will be achieved through collaboration with secondary and tertiary training establishments. This broader educational outreach is set to inspire people on the Islands to be involved in electric aviation whether through direct engineering or by getting involved in infrastructure, energy generation, or any of the other industries that aid in successful aviation operations on the islands.

5.7. Training and Maintenance References

Contacts and authorities for training and maintenance

None.

Websites and documents for training and maintenance

1. KLM MRO: https://www.afiklmem.com/en
2. EASA: https://www.easa.europa.eu/en
3. FAA: https://www.faa.gov/
4. EASA NPA 2020-12: https://www.easa.europa.eu/en/document-library/notices-of-proposed-amendment/npa-2020-12
5. EASA NPA 2021-15: https://www.easa.europa.eu/en/npa-2021-15
6. EASA Part 66: https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-continuing-airworthiness-0
7. EASA Part 147: https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-continuing-airworthiness-0

6. Regulatory Requirements and Demonstration Flight Planning

This section describes the regulatory requirements for operating various aircraft in the ABC Islands and the types of flights being considered for pilot operations in the ABC Islands. Regulatory and planning factors that were researched and presented in this section include flying experimental aircraft in the region, flying a single engine aircraft over water, flying in low visibility or inclement weather conditions, regulations specific to each island, and other considerations specific to the region.

6.1. Regulatory Requirements

This section is associated with Work Package 6. It describes the requirements the Dutch Ministry, Ampaire, and the Hybrid Caravan must comply with to perform the described pilot operations in the ABC Islands. For pilot operations, it would be Ampaire's responsibility, under the supervision of the Dutch Ministry, to assure that all rules and requirements are complied with.

Under ICAO regulations, for aircraft to be allowed to fly by the aviation authorities, they require a:

- Type Certificate (TC): proof that the type design is safe.
- Certificate of Airworthiness (CoA): proof that an individual aircraft has been produced in accordance with the TC and maintained in accordance with Continued Airworthiness requirements for inspections, maintenance, repairs etcetera through its operational life.

6.1.1. Regulatory Considerations for Pilot Operations

From initial discussions, both Aruba and Curaçao CAAs have indicated that they would likely leverage Ampaire's existing FAA provided experimental airworthiness certificates for our initial pilot flights, and that no additional cost would be incurred. Timescales vary depending on CAA workload and complexity of the application, but a minimum timeframe of 3 weeks should be allowed for processing.

A meeting was held with the Netherlands CAA (ILT), to discuss this process. The below link to the application form was provided. The fee associated with obtaining a permit to fly for an aircraft is € 76, and a notional timeline of approximately 2 weeks should be allowed for processing, although this varies with complexity.

Link to ILT website for permit to fly, Application national permit to fly (ILT.231):

https://english.ilent.nl/documents/forms/2016/06/01/form-application-national-permit-to-fly-ilt.231

IenW is working on defining the experimental aircraft chapter in national regulations (Regulation on National Safety Regulations for Aircraft), where experimental aircraft may be included in Annex I of the European Basic Regulation for Aviation (BES). The expectation is that this will come into effect in early 2024.

Until then, the exemption provision in the Aviation Act can be used to fly without a valid airworthiness certificate as specified in Article 3.8/3.21 of the Aviation Act. The Aviation Act applies to the Amsterdam Flight Information Region (the Dutch part of European airspace). The Aviation Act determines that Chapters 2, 3, and 4 are similarly applicable to the BES. In the ministerial regulations regarding licensing, airworthiness, and flight operations, it is also stipulated that the BR and the relevant implementing regulations are similarly applicable to the BES. Additionally, there is a separate Aviation Act for the BES.

The Inspection for the Environment and Transport issues the exemption on behalf of the Minister to fly with an experimental aircraft. The ILT assesses compliance with the Exemption Framework for Airworthiness 2015. The framework includes provisions for granting exemptions for experiments. Additionally, the ILT will assess the airworthiness of the experimental aircraft. Exemptions are issued for the duration of the experiment and are therefore temporary and operationally limited. It is not allowed to conduct commercial activities with the exemption; the transportation of passengers and cargo is thus excluded.

6.1.2. Flight over Water Regulatory Considerations

There are two main concerns related to single-engine aircraft that should be explored for their potential impact on either demonstration flights or commercial roll out of the Hybrid Caravan within the ABC Islands:

- Flight over water
- Night and IMC (IFR) Operations

There are no EASA or FAA regulations that prevent flight operations under these conditions, however both authorities have regulations that restrict flight operations in these areas.

Single-engine aircraft are permitted to fly over water, but there are certain regulations and safety considerations that pilots must follow, including the carrying of additional safety equipment. The main concern is that if an engine failure occurs over water, the pilot must be able to land safely on the surface of the water or reach a suitable shore.

Additionally, local CAAs introduce regulations in certain regions that restrict or discourage single-engine aircraft from flying over water. These regulations are typically put in place for safety reasons, though they are not generally specific to aircraft type or configuration.

Where there are no local restrictions, ultimately, it is up to the pilot to make the decision about whether it is safe to fly over water in a single-engine aircraft based on their experience, training, the capabilities of the aircraft, and the specific conditions of their flight.

EASA Regulations related to Single-Engine Flights over Water

EASA regulations related to commercial operations of aircraft over water are provided in Easy Access Rules for Air Operations (refer to the References section for details and link).

A summary of the EASA regulations as they relate to Hybrid Caravan operations within the ABC islands are:

> If the aeroplane is operated over water at a distance greater than 50Nm from shore then the aeroplane shall be equipped with life-jackets.

In the case that the hybrid caravan is classified as a single-engined aircraft then the following regulation also applies:

> For aeroplanes operated over water at a distance away from land suitable for making an emergency landing, greater than that corresponding to 30 minutes at cruising speed or 100 NM, whichever is the lesser, then the aeroplane shall carry life rafts, survivor locator lights, life saving equipment and at least two survival ETLs.

Some flight routes in the ABC islands exceed the 30 minutes or 50NM flight time/distance over water [1]. And therefore, the interpretation between single engine and multi-engine for safety considerations become significant.

FAA Regulations related to Single-Engine Flights over Water

The Federal Aviation Administration (FAA) has established regulations for overwater flights in general aviation operations under Part 91 of the Federal Aviation Regulations (FARs).

FAR Part 91.205 [2] requires that all aircraft, including single-engine aircraft, be equipped with the necessary equipment for the type of operation being conducted. For overwater flights, beyond power-off gliding distance from shore, this includes carrying approved flotation gear readily available to each occupant. It is not clear if the definition of approved flotation gear includes rafts as well as life vests. Refer to Appendix A for a complete text of the requirement.

Furthermore, the FAA also provides guidelines for extended overwater operations for small aircraft in Advisory Circular AC 91-70A [3]. This circular provides guidance for pilots conducting overwater flights and includes information on planning, weather considerations, emergency procedures, and equipment requirements. This document stipulates “Single-engine aircraft will carry life rafts when operating more than 100 NM from shore and multi-engine aircraft will carry them when operating more than 200 NM from shore”.

Aruba Regulations Related to Single-engine Flights Over Water

AUA-OPS 1.542 (En-Route – Single-engine Aeroplanes) states:

> “The operator shall ensure that the aeroplane, in the meteorological conditions expected for the flight, and in the event of engine failure, is capable of reaching a place at which a safe forced landing can be made. For landplanes, a place on land is required, unless otherwise approved by the Authority. (See AMC OPS 1.542(a).)”

This regulatory text goes on to describe the methods to be used to show compliance to this requirement based on a rate of descent calculation.

Elsewhere in the regulations (AUA-OPS 1.526), a safe forced landing is defined as a “safe forced landing to be an area at which it can reasonably be expected that it will not lead to serious injury or loss of life”.

Curaçao Regulations Related to Single-engine Flights Over Water

Curacao CAA has furnished Ampaire with the relevant CCAR regulations in this area.

Within these documents VFR, daylight flights over water are permitted so long as they are carried out on "such routes and diversions there from that permit a safe forced landing to be executed in the event of an engine failure.”, per CCAR regulation 8.7.2.3. there are further restrictions where flights over water combined with being performed at night or under IFR.

6.1.3. Flight at Night or in Bad Weather (IFR) Regulatory considerations

This part of the study is limited to exploring the regulations related to single-engine aircraft only. The primary purpose of understanding these operational limitations is to understand the operational and commercial impact on potential airline operators in the area.

EASA requires the operator shall ensure that operations of single-engined aeroplanes are only conducted along routes, or within areas, where surfaces are available that permit a safe forced landing to be executed. We can interpret that water would not constitute a surface that would permit a safe forced landing unless the aircraft were equipped with floats.

Single engine turbine aircraft operators can seek an approval for night or bad weather operations under Annex V (Part-SPA), Subpart L — SINGLE-ENGINED TURBINE AEROPLANE OPERATIONS AT NIGHT OR IN IMC (SET-IMC). One of the acceptable means of compliance for the route proving part of the process is to limit the risk by limiting the amount of time over water to 15 minutes with the following exception:

> "… unless the operator has established, based on a risk assessment carried out for the route concerned, that the cumulative risk of fatal accident due to an engine failure for this flight remains at an acceptable level (see GM2 SPA.SET-IMC.105(d)(2))." It is quite possible that Ampaire can support the operator in making the case for this risk assessment based on the multiple layers of redundancy within the hybrid powertrain system.

It would appear that the CAT.OP.MPA.136 requirement is relevant to all single-engined operations, however it is noted that the approval to be sought reference is specific to night and IMC conditions (SET-IMC). Further clarification is required for the case of day time VFR operations.

In 1998 the FAA introduced additional rules to increase the safety of and allow IFR operations in single-engined aircraft.

In summary, these rules require:

- The certificate holder to incorporate into its maintenance program engine trend monitoring
- Each aircraft to have either two independent electrical power generating sources or in addition to the primary electrical power generating source, a standby battery or an alternate source of electric power that is capable of supplying 150% of the electrical loads of all required instruments and equipment necessary for safe emergency operation of the aircraft for at least one hour.

Aruba Regulations Related to Single-engined Night and IMC (IFR) Operations

Nighttime and IFR flights with single-engined aircraft are not permitted without specific approval from the Authority.

The regulations provide some useful guidance on what is expected in order to obtain this permission, e.g. "the reliability of the turbine engine shall be shown to have a power loss rate of less than 1 per 100,000 engine hours", with a note that "Power loss in this context is defined as any loss of power, the cause of which may be traced to faulty engine or engine component design or installation, including design or installation of the fuel ancillary or engine control systems."

Once again, an engine trend monitoring system and process must be employed by the operator.

Certain on-board equipment is also prescribed by the Authority before they will permit these operations. These include the requirement for “two separate electrical generating systems”, as well as “a certified area navigation system capable of being programmed with the positions of aerodromes and safe forced landing areas, and providing instantly available track and distance information to those locations” amongst others.

Curaçao Regulations Related to Single-engined Night and IMC (IFR) Operations

Operation of a single-engined aircraft at night or under IFR is not permitted, unless special permission has been granted by the authority. This permission may be granted for propeller driven, turbine powered aircraft, with a maximum passenger seating configuration of 9, under the current rule-set. As described in the FAA regulations, the operator must have an engine trend monitoring program in place amongst other things and be able to demonstrate significant reliability before these permissions will be considered by the authority.

6.1.4. Regulatory Conclusion

During Phase 1, Ampaire researched and studied the regulatory requirements for Phase 2 Pilot Operations. Ampaire concludes that the needs and requirements for operating in the ABC Islands are similar to and align with the needs and requirements for demonstration flights that the company has previously performed. Ampaire can leverage this experience to efficiently execute pilot operations, and perceived no barriers for Phase 2 pilot operations execution, which would be carried out during daytime under VFR conditions.

A common thread of the rule sets reviewed is that single-engined aircraft must be able to glide to a safe forced-landing area, which we can interpret as being on land, and that a glide slope (rate of descent, with engine failed) calculation-based approach to meeting this regulation is expected. In practice this means that if the hybrid-caravan were to be classified as a standard single-engined aircraft (with no credit given to the additional redundancy that the electric “boost” system provides) then the pilot would need to climb the aircraft to a suitable altitude to ensure that the safe-forced landing area can be reached in the event of a failure.

Regulations also specify that certain safety equipment must be carried for operations beyond specified distances from shore. Of these regulations, the EASA regulations are the most limiting operationally. For the EASA regulations the distance from shore that Life-rafts would need to be carried on board equate to approximately 73NM distance from shore (calculated for 30mins at an approximate cruise speed of 146 kts).

For commercial single-engined night and IMC (IFR) operations to be performed by single-engined aircraft in the ABC islands, a special approval must be sought which requires evidence that these operations can be achieved safely through the combination of additional onboard safety equipment and proof of engine reliability.

If the Hybrid Caravan were to be classified as a multi-engined aircraft by the airworthiness authorities, then these regulations would not apply. However, in the case that the aircraft is classified as single-engined, the additional benefits resulting from the graceful degradation in engine performance, which arise from the Ampaire hybrid architecture, should be factored into the process of seeking special permission to operate under IFR and at night.

6.1.5. Regulatory References

Contacts and authorities for regulatory information

- Persoonsgegevens
- Persoonsgegevens
- Persoonsgegevens

Websites and documents for regulatory information

1. ACAO ICAO, Aircraft Certification – Including Modifications; (spacing intentional) https://www.icao.int/MID/Documents/2019/ACAO-ICAO%20Airworthiness/Session%205%20Part%2021%20%20Aircraft%20Certification%20final.pdf
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4. European Union Aviation Safety Agency, Easy Access Rules for Air Operations (Regulation [EU] No 965/2012); https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-air-operations-regulation-eu-no-9652012
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6. Ministerial Regulation of October 2nd, 1995, nr. 4 in implementation of articles 10 and 20 of the Aviation Order (AB 1989 nr. GT 58), Airworthiness Regulation; (spacing intentional) https://s3.amazonaws.com/dev.asf-uploads/regulations/AUA-RLW%20Airworthiness%20Regulation%20.pdf
7. Memo from Persoonsgegevens Dated 22 August 2023
8. U.S. Code of Federal Regulations, Title 14; https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-91/subpart-C/section-91.205
9. U.S. Department of Transportation, Federal Aviation Administration, 14 CFR Part 135 [Docket No. 28743; Amendment No. 135–70], RIN 2120–AG22, Commercial Passenger-Carrying Operations in Single-Engine Aircraft Under Instrument Flight Rules; https://www.govinfo.gov/content/pkg/FR-1997-08-06/pdf/97-20641.pdf
10. U.S. Department of Transportation, Federal Aviation Administration, Advisory Circular for operators planning oceanic flights; https://www.faa.gov/documentlibrary/media/advisory_circular/ac%2091-70a.pdf

Appendices

Refer to the following appendices for details and links providing ABC Islands regulatory information.

- Appendix A – EASA Regulation Digest & links
- Appendix B – FAA Regulation Digest & Links
- Appendix C – Curaçao Regulation Digest & Links

- Appendix D – Aruba Regulation Digest & Links
- Appendix E – ICAO Regulation Digest & Links
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6.2. Pilot Operations Flight Planning

This section is part of Work Package 6. It provides examples of flight routes and example flight schedules that could be flown during pilot operations. The goal of these flights is to demonstrate hybrid aircraft flight and turnaround at and between the islands. Weather, air traffic busy times, peak visitation, and other factors were considered.

Ampaire recommends using the Queen Beatrix International Airport at Aruba as the base of operations for pilot operations. Based on the initial infrastructure study completed in July 2023, Ampaire found the hangar facilities and electrical charging capability already capable for the needs of the program, and the airport operations personnel are willing to support.

Phase 2 Pilot Operations Assumptions

For the purposes of planning and focus, Ampaire has made the following assumptions concerning pilot operations in the ABC Islands. These may change over time as the project evolves, stakeholder involvement increases, and we learn more.

1. It has been assumed that the Hybrid Caravan will be pre-certification, at the time of pilot operations.
2. We will be working with 3 separate CAAs, each with their own processes for granting special airworthiness permissions for the pre-certification Hybrid Caravan.
3. Aruba and Curacao regulations are ICAO aligned, and as they are independent countries, they are free to accept FAA Experimental certification. Ampaire can extend the existing Hybrid Caravan FAA certification to cover the islands operations.
4. Bonaire is a special municipality of the Netherlands, and as such falls under the governance of the ILT (Dutch CAA). Regulations are still in development, however the ILT have confirmed that an exemption would be required by obtaining a “National Permit to Fly”. This process is anticipated to be similar to the requirement Ampaire experienced when gaining permission to conduct flight trials of our hybrid Cessna 337 in the UK. A risk-based approach is taken by the authorities and usually consists of the supply and review of the following documentation, which are to be generated and provided in Phase 2.
    a. Leverage existing permissions, such as FAA granted experimental certificates
    b. Concept of Operations
    c. Flight test templates
    d. Fire brigade training/ briefings
    e. Hazard register (Risk assessment)
    f. Aircraft Maintenance and Inspection Plan
    g. Aircraft registration Documentation
    h. Flight Manual Supplement
    i. Pilot qualifications and Medical

6.2.1. Pilot Operations in the ABC Islands

The Hybrid Caravan will fly a series of flights to prove viability of operating a hybrid aircraft in the ABC Islands. These flights will simulate typical air carrier schedules and one series of flights are planned to simulate medical airlift scenarios.

Expected flight times and maximum fuel burn are included for each route. Flight times and fuel burn will vary depending on factors like temperature and wind. Fuel used during actual flights (fuel burn) is calculated to be a conservative 77% of typical Cessna Grand Caravan 208B for safety, with the expectation that efficiency will exceed this estimate. Fuel savings could be more than the predicted 23%, and data will be collected during the flights to determine actual fuel consumption.

Circumventing restricted airspace is accounted for in the example flight routes and schedules, but provisions for unforeseen incidents or diverts causing extended flight times are not. For the example schedules, flight times were sampled on two different days a month apart and averaged. Though specific waypoints are used in the routes described in the next sections, Ampaire's pilots will plan and fly VFR flights between the islands the days prior to the actual flights. Therefore, the pilot is not limited to flying exactly to the waypoints indicated but will be using visual navigation and established routes most of the time. The waypoints are be used as a reference for aligning the aircraft along the desired route.

6.2.2. Airspace Considerations that May Cause Additional Flight Time

Special considerations apply when flying in any airspace. Established flight routes help pilots avoid restricted airspace, denoted on aeronautical charts by a shape bordered with blue hashmarks. An area may be restricted due to environmental or noise factors, national defense, or national security reasons. Flying over restricted airspace is prohibited unless the flight is experiencing an emergency or other special circumstances, which are coordinated with ATC. Because of this, flying a straight, direct path is not always possible. The need to route around restricted airspace can add several minutes to total flight time.

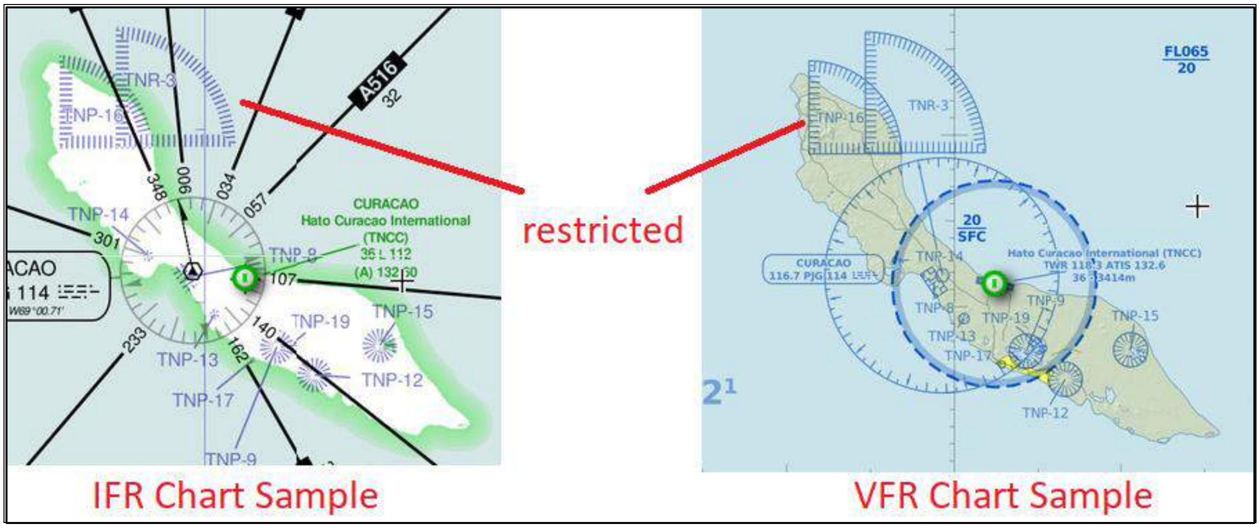


Figure 9 - Restricted Airspace Demarcation

Other factors that can extend flight times are:

- An issue with the intended destination, such as an incident that temporarily closes the runway
- Diverting around weather or high winds
- Greater than normal amounts of air traffic, causing ATC to sequence many aircraft for landing in a short period of time, causing one or more aircraft to circle to give landing aircraft more time

It is for these reasons that all aircraft are required to fly with an additional 30 to 45 minutes of fuel for every scheduled flight.

6.2.3. Other Factors that May Cause Additional Flight Time

Another factor that may add to the flight time is the type of airworthiness certificate held by the Hybrid Caravan. Should the Hybrid Caravan remain under an experimental airworthiness certificate, the pilot will be required to avoid all populated areas, denoted by yellow shapes on the sectional chart. These areas are typically avoided by all aircraft and air carriers when possible, but in some cases, there is no choice but to fly over areas with dense populations. If the Hybrid Caravan remains "experimental," the pilots may have to reroute the aircraft significantly.

The restriction for flying over densely populated areas does not apply if the Hybrid Caravan has completed the STC and is operated using a standard airworthiness certificate. Every effort will be made to achieve the STC prior to pilot operations.

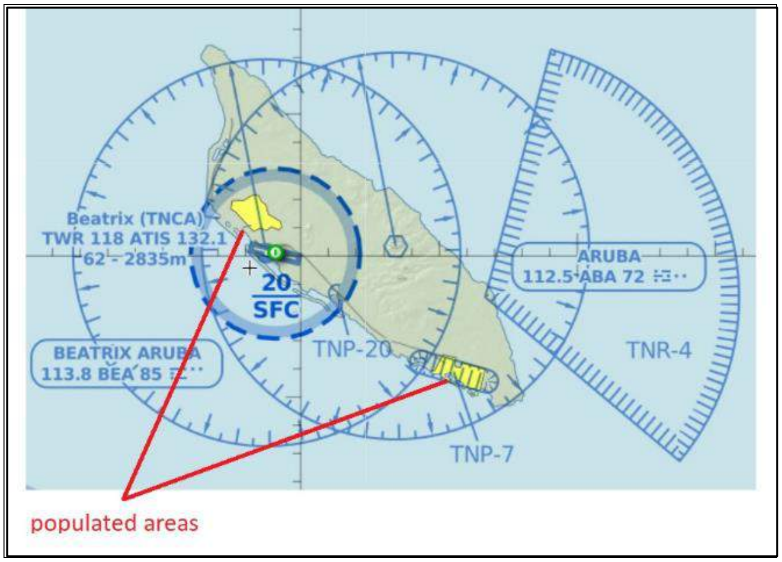


Figure 10 - VFR Chart Depiction of Populated Areas

6.2.4. Route Data

The anticipated actual fuel use for the routes in the next sections comes from the projected DOC savings study completed in DM1F-GPO-006001 Preliminary Route Assessment – Dutch ABC Islands, Rev B, 13 May 2023 submitted earlier this year, the content of which is updated in this document. The study results indicate between 14% and 32% fuel savings for all routes: an average of 23%. Therefore, the fuel calculations for each route are figured at 77% of what a standard Cessna Grand Caravan 208B would use. Refer to Figure 11.

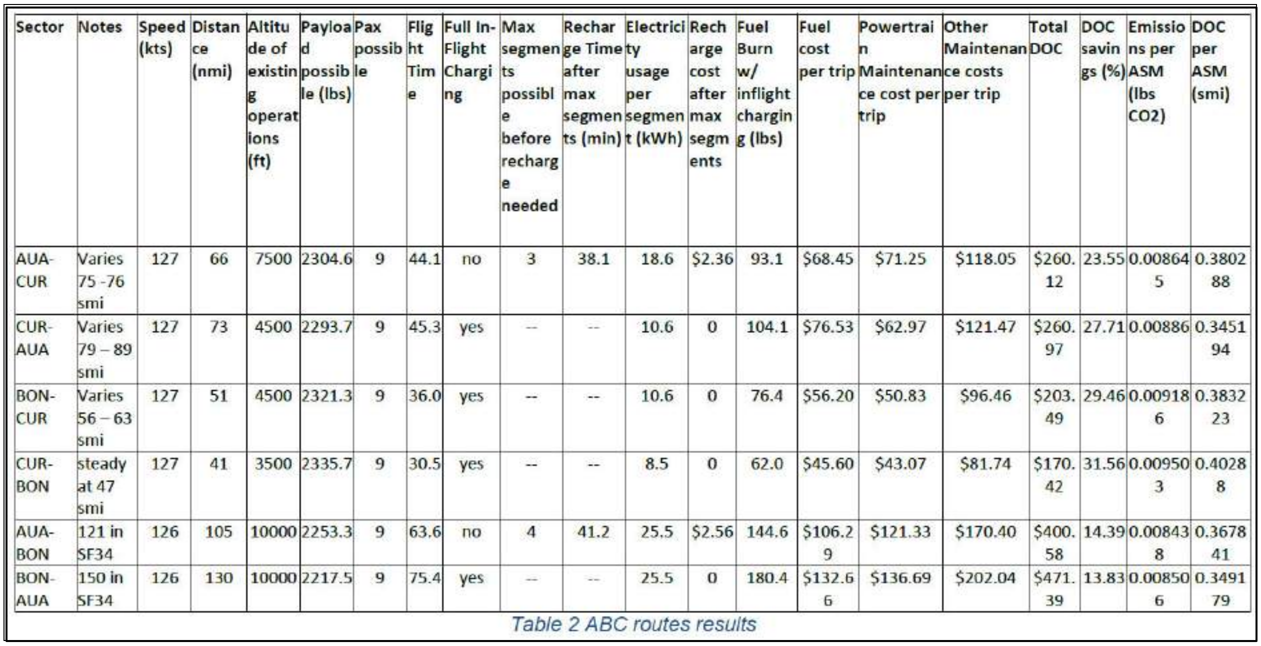
Sustainable aircraft fuel (SAF) is not yet in use in the ABC Islands, however, blends of aviation fuel using sustainable kerosene may be available. If so, this will be the first choice for aircraft refueling.

The following table contains averages for the Hybrid Caravan for the routes described and can be used for flight planning and cost estimating purposes. Flight time and fuel burn calculations are based on a standard 208B model aircraft. The 77% Hybrid Caravan estimated fuel burn in gallons calculation is based on the DOC study performed earlier this year.

The following tables are used to estimate data for specific flights.

Route	Flight Time, Minutes	208B Fuel Burn, Gallons	77% Fuel Burn, Gallons
TNCA – TNCB	50	26.4	19.4
TNCA – TNCC	33	16.5	12.8
TNCB – TNCA	41	16.1	12.4
TNCB – TNCC 1	16	6.5	5.0
TNCB – TNCC 2	32	15.3	11.8
TNCC – TNCA	24	11.5	8.8
TNCC – TNCB	21	9.5	7.3

TNCA: Aruba, TNCB: Bonaire, TNCC: Curaçao



Sector	Notes	Speed (kts)	Distance (nmi)	Altitude of existing operations (ft)	Payload possible (lbs)	Pax possible	Flight Time	Full In-Flight Charging	Max segments possible before recharge needed	Recharge Time after max segments (min)	Electricity usage per segment (kWh)	Recharge cost after max segments	Fuel Burn w/ inflight charging (lbs)	Fuel cost per trip	Powertrain Maintenance cost per trip	Other Maintenance costs per trip	Total DOC	DOC savings (%)	Emissions per ASM (lbs CO2)	DOC per ASM (smi)
AUA-CUR	Varies 75 -76 smi	127	66	7500	2304.6	9	44.1	no	3	38.1	18.6	$2.36	93.1	$68.45	$71.25	$118.05	$260.12	23.55	0.008645	0.380288
CUR-AUA	Varies 79 – 89 smi	127	73	4500	2293.7	9	45.3	yes	--	--	10.6	0	104.1	$76.53	$62.97	$121.47	$260.97	27.71	0.00886	0.345194
BON-CUR	Varies 56 – 63 smi	127	51	4500	2321.3	9	36.0	yes	--	--	10.6	0	76.4	$56.20	$50.83	$96.46	$203.49	29.46	0.009186	0.383223
CUR-BON	steady at 47 smi	127	41	3500	2335.7	9	30.5	yes	--	--	8.5	0	62.0	$45.60	$43.07	$81.74	$170.42	31.56	0.009503	0.40288
AUA-BON	121 in SF34	126	105	10000	2253.3	9	63.6	no	4	41.2	25.5	$2.56	144.6	$106.29	$121.33	$170.40	$400.58	14.39	0.008438	0.367841
BON-AUA	150 in SF34	126	130	10000	2217.5	9	75.4	yes	--	--	25.5	0	180.4	$132.66	$136.69	$202.04	$471.39	13.83	0.008506	0.349179

Table 2 ABC routes results

Figure 11 - ABC Islands Routes Fuel Calculations for Hybrid Caravan

6.2.5. Proposed Flight Missions and Example Schedules

A few different missions are proposed to evaluate the Hybrid Caravan as a carrier solution for the ABC Islands. The first is a familiarization mission where flight and ground crews become familiar with operating and handling the aircraft. This activity makes the data captured during the next missions more accurate as most of the learning is taken out of the equation. The air carrier mission evaluates the practicality of using the Hybrid Caravan as a passenger and cargo transport between islands including turnaround time. The medical airlift mission demonstrates using the Hybrid Caravan for medical transport purposes using the farthest distance between islands to establish a baseline.

Several factors were considered to establish the proposed pilot operations demonstration flight schedules. Major considerations are Hybrid Caravan aircraft airworthiness and availability, typical weather patterns and temperatures, high and low tourism seasons, peak airspace use times, number of departing and arriving flights or each airport, and existing airport infrastructure.

In summary, the best time of year to fly pilot operations for this program is in November and scheduling flights in the early morning hours and concluding by mid-afternoon.

There are approximately twice as many flights per day between Curaçao and Bonaire than Curaçao and Aruba. Keeping fewer legs in the demonstration schedule allows for appropriate crew rest in case of delays due to weather, fueling issues, or maintenance.

Ampaire recommends a base of operations at TNCA Oranjestad Queen Beatrix Airport, Aruba (AUA) due to the readiness of existing infrastructure and the wiliness of local airport authorities and personnel to support the project. Departures from Aruba can occur early enough to deconflict with departures and arrivals at all other airports and avoid the mid-afternoon peak air traffic times.

The busiest time in the morning for all airports is the 8 o'clock hour. The example schedules take this into account and mostly avoid arriving or departing an island airport during this hour. The busiest times in the afternoons are 13:00 to 16:00 local time on Saturdays, and mid-afternoon every day is busy for the region. Mid-day flights are few. Ampaire will avoid mid-afternoon flights for pilot operations as much as possible to avoid the busiest time of day for all airports, and afternoon is also the most likely time of day for thunderstorms and precipitation.

6.2.6. Familiarization Mission Example

This example schedule assumes that Aruba's airport is the base of operations.

The purpose of the familiarization mission is to allow the pilots and ground crews to practice the flight routes and turning the aircraft around for the next flight. The target time for aircraft turnaround is 30 minutes, but additional time is allotted between landing and takeoff (turnaround) during the familiarization mission to compensate for any unfamiliarity with equipment and ground handling.

During the 45 allotted minutes in this schedule, ground crews will simulate or perform turnaround tasks such as guiding, parking, towing, charging, fueling, and launching. During turnaround time, pilots will make notes regarding aircraft performance during the leg flown and perform a through-flight inspection after servicing and ground handling is complete.

If weather or other factors prevent any part of the familiarization mission from being performed, the team determines whether to perform those legs on a different day, proceed with one of the demonstration missions, or return to base.

Fam Mission	Origin	Depart Time	Destination	Arrive Time	Duration m	LDG Fees	77% Fuel Used
Briefing	TNCA	06:00					
Pax / Cargo	TNCA	06:30	TNCC	07:03	33	$41.35	12.8
Pax / Cargo	TNCC	07:48	TNCB	08:09	21	$15.00	7.3
Debrief	TNCB	08:40					
Medical Airlift	TNCB	09:40	TNCA	10:21	41	$11.26	12.4
Medical Return	TNCA	11:06	TNCB	11:56	50	$15.00	19.4
Lunch	TNCB	12:30					
EOD Debrief	TNCB	13:30					
Totals					**145, 2h 25m**	**USD $82.61**	**USG 51.9**

TNCA: Aruba, TNCB: Bonaire, TNCC: Curaçao

Fam Mission	Origin	Depart Time	Destination	Arrive Time	Duration m	LDG Fees	77% Fuel Used
Briefing	TNCB	06:00					
Pax / Cargo	TNCB	06:30	TNCC	07:02	32	$41.35	11.8
Pax / Cargo	TNCC	07:47	TNCA	08:11	24	$11.26	8.8
Debrief	TNCA	09:15					
Medical Airlift	TNCA	10:15	TNCB	11:05	50	$15.00	19.4
EOD Debrief	TNCB	12:15					
Totals					**106, 1h 46m**	**USD $67.61**	**USG 43.4**

TNCA: Aruba, TNCB: Bonaire, TNCC: Curaçao

6.2.7. Air Carrier Schedule Simulation Example

This example schedule assumes Aruba’s airport is the base of operations.

This schedule simulates the typical flight morning of an existing, small air carrier. The purpose is to determine the feasibility of using the Hybrid Caravans as a passenger and cargo transport between the islands. A 30-minute turnaround is targeted.

AC Mission	Origin	Depart Time	Destination	Arrive Time	Duration m	LDG Fees	Fuel Used
Briefing	TNCA	06:00					
Pax / Cargo	TNCA	06:30	TNCC	07:03	33	$41.35	12.8
Pax / Cargo	TNCC	07:33	TNCB	07:54	21	$15.00	7.3
Pax / Cargo	TNCB	08:24	TNCC	08:56	32	$41.35	11.8
Pax / Cargo	TNCC	09:26	TNCB	09:47	21	$15.00	7.3
Pax / Cargo	TNCB	10:17	TNCC	10:49	32	$41.35	11.8
Pax / Cargo	TNCC	11:19	TNCA	11:43	24	$11.26	8.8
EOD Debrief	TNCA	12:45					
Totals					**163, 2h 43m**	**USD $165.31**	**USG 59.8**

TNCA: Aruba, TNCB: Bonaire, TNCC: Curaçao

AC Mission	Origin	Depart Time	Destination	Arrive Time	Duration m	LDG Fees	Fuel Used
Briefing	TNCB	06:00					
Pax / Cargo	TNCB	06:30	TNCC	07:02	32	$41.35	11.8
Pax / Cargo	TNCC	07:32	TNCA	07:56	24	$15.00	8.8
Pax / Cargo	TNCA	08:26	TNCC	08:59	33	$41.35	12.8
Pax / Cargo	TNCC	09:29	TNCB	09:50	21	$15.00	7.3
Pax / Cargo	TNCB	10:20	TNCC	10:52	32	$41.35	11.8
Pax / Cargo	TNCC	11:22	TNCB	11:43	21	$15.00	7.3
EOD Debrief	TNCB	12:45					
Totals					**127, 2h 43m**	**USD $169.05**	**USG 59.8**

TNCA: Aruba, TNCB: Bonaire, TNCC: Curaçao

6.2.8. Medical Airlift Mission Example

Bonaire’s airport is the base of operations for medical airlift missions.

This mission simulates the response of alerted medical aircrew to a medical emergency on Aruba or Curaçao. The goal of a medical airlift is to have a quick turnaround time of 15 minutes or less. This exercise provides an opportunity to push the aircraft and crew to perform as efficiently as possible.

MA Mission	Origin	Depart Time	Destination	Arrive Time	Duration m	LDG Fees	Fuel Used
Briefing	TNCB	06:00					
Medical Airlift	TNCB	06:30	TNCA	07:11	41	$11.26	12.4

Med Return	TNCA	07:26	TNCB	08:16	50	$15.00	19.4
Medical Airlift	TNCB	08:31	TNCC	09:03	32	$41.35	11.8
Med Return	TNCC	09:18	TNCB	09:39	21	$15.00	7.3
Debrief	TNCB	10:30					
Totals					**144, 2h 24m**	**USD $82.35**	**USG 50.9**

TNCA: Aruba, TNCB: Bonaire, TNCC: Curaçao

6.2.9. Airspace and Airport Fees

Every airport in the ABC Islands requires landing fees. Fees are standard under 3,000kg. Aircraft weighing more than 3,000kg have a different fee structure. These fees are based on the aircraft's maximum takeoff weight (MTOW). The prototype Hybrid Caravan MTOW is 9,062 lbs., 4,110 kg. (Note: the Hybrid Caravan prototype used for pilot operations will have a different weight due to modifications to the current prototype configuration.) Therefore, the standard fees cannot apply, and calculations were required to determine landing fees for each airport.

The DCCA are developing an incentivization package for hybrid and electrified aircraft to help reduce air carrier operational costs. At the time of this document's publication, these incentives are in work ad are not yet in effect.

Aircraft MTOW (as of October 2022)	9,062lbs, 4,110kg
Fuel Burn Rate at Cruise	34 GPH
Fuel Capacity	335 gallons

Airspace use also requires a fee. If the Dutch Ministry can designate the Hybrid Caravan an aircraft making test flights at the request of the CAA, it may be possible to waive air navigation service charges.

Parking fees are free for the first 2 hours. The aircraft should not be on the ground longer than 45 minutes during pilot operations.

Airport	Fee	Cost per landing
TNCA	USD$2.74 per MTOW (4,110 kg) or part thereof	4,110 x $2.74 = USD$11.26
TNCB	USD$3.00 per 1,000kg or part thereof	5,000 x $3.00 = USD$15.00
TNCC	USD$8.27 per 1,000kg or part thereof	5,000 x $8.27 = USD$41.35

TNCA: Aruba, TNCB: Bonaire, TNCC: Curaçao

6.2.10. Specific route example – Aruba to Curaçao

A smaller aircraft like the Hybrid Caravan can use narrow corridors. For this example, it is possible to navigate on Aruba between two no-fly areas, TNP-7 and TNR-4, when the winds favor runway 11 at the Aruba airport.

This route planned in Figure 12 uses the Aruba VOR ground instrument to align the aircraft with the corridor. The next waypoints of the route consist of established navigation points GUBIV and ROLBO. Approaching Curaçao, the PJG VOR is used to align the aircraft with the destination airport. The pilot needs to be cognizant of the TNP-8 no-fly airspace on approach to Curaçao airport and make minor adjustments as needed to avoid overflying it. This is a very conservative way to plan a flight and can be less efficient than a more lenient approach.

Figure 13 shows an actual VFR flight using visual references and standard navigation, which in this case is much more efficient. The pilot of this privately-owned aircraft navigated between the restricted air spaces on Aruba then likely chose a compass heading and used visual cues to navigate directly to the Curaçao airport. This approach can be possible for commercial aircraft as well depending on airspace rules.

TNCA – TNCC

Flight Plan

Aircraft N405GV Spd 160 Alt 035 Fuel 335

Departure TNCA Beatrix Airport

Destination TNCC Hato Curacao International Airport

ETD Zulu HHMM MM/DD Local HHMM MM/DD

Dist: 68.7 ETE: 35 min Burn: 17.6

→ ABA → ELOTU → ROLBO →

Figure 12 - Aruba to Curaçao Planning Chart Example

Figure 13 - Actual General Aviation Tracked Flight from Aruba to Curaçao

The following table shows the way flight times and fuel were calculated for flight planning. The information was calculated using Skyvector.com on two different days a month apart. These variations give us a picture of the time and fuel ranges the pilots may experience when flying this route. Similar calculations were performed for each route.

TNCA-TNCC	Flight Time	Typical Fuel Use	77% of Fuel Use
Day 1	31 minutes	15.4 gallons	11.9 gallons
Day 2	35 minutes	17.6 gallons	13.6 gallons
Average	**33 minutes**	**16.5 gallons**	**12.8 gallons**

TNCA: Aruba, TNCC: Curaçao

6.2.11. Pilot Operations Flight Planning References

Contacts and authorities for demonstration flight planning

None.

Websites and documents for pilot operations flight planning

1. Aircraft Owners and Pilots Association, Overall Pilot, Passenger, and Aircraft Requirements for flying in the Caribbean: https://www.aopa.org/travel/international-travel/caribbean
2. Aruba, AUA Airport Traffic Statistics, November 2022; https://www.airportaruba.com/storage/app/uploads/public/63a/d91/ca3/63ad91ca302db624319790.pdf
3. DC-ANSP, Concept of Operations DC-ANSP airspace and route design; https://gobiernu.cw/wp-content/uploads/2021/02/CONOPS-Airspace-Redesign-v2-signed-1.pdf
4. DC-ANSP, electronic aeronautical information publication (eAIP); https://dc-ansp.org/eAIS/eAIP-Publications/2023-04-20/html/index-en-GB.html
5. Dutch Caribbean Air Navigation Service Provider ATM Contingency Plan Curaçao FIR; https://www.icao.int/NACC/Documents/eDOCS/ATM/CPlans/ContPlan-CUR.pdf
6. Dutch Caribbean Air Navigation Service Provider, Part 1 – General, Section 4.1 – Airport Charges; https://dc-ansp.org/
7. Dutch Caribbean Air Navigation Service Provider, Part 1 – General, Section 4.2.3.2 – Exemptions/reductions; https://dc-ansp.org/
8. Hybrid Caravan current weight and balance, C5E5-08401Y-R020-0_AD_hybridCaravan Detailed Weight Accounting & BOM, Hybrid FF W&B
9. Skyvector.com: flight route planning, flight durations, fuel burn estimates; https://skyvector.com/
10. Time and Date, astronomical data for flight planning; https://www.timeanddate.com/sun/@4644875?month=3&year=2024
11. Where and When, Best time to go to the Dutch Antilles; https://www.whereandwhen.net/when/caribbean/netherlands-antilles/
12. World Weather Online, Oranjestad Annual Weather Averages; https://www.worldweatheronline.com/oranjestad-weather-averages/an.aspx

7. Conclusion

As a result of this study, Ampaire has concluded that Hybrid Caravan (non-commercial) pilot operations in the Dutch ABC Islands are feasible. Regulatory requirements for such operations are reasonable and can be complied with, proposed routes can be flown safely, enough infrastructure exists or will exist to support pilot operations and crew, there are safe and appropriate means to get the proposed aircraft and specialized equipment to the islands and have the aircraft hangared and equipment stored, and there is enough local talent and skilled professionals to help support and maintain the aircraft. Pilot operations can go forward to prove out the viability of operating electrified aircraft in the region with opportunities for training local ground handlers, mechanics, and technicians to support electrified aircraft.

The encouraging results of this study suggest that the Dutch Leeward Islands, Saba, Sint Eustatius and Sint Maarten, might also benefit from a similar activity.

After pilot operations are completed in the ABC Islands, the actual efficiencies and cost savings will be known with increased confidence having been achieved through measurement as well as modeling. The result will be a strengthening of relationships with air carriers, MRO partners, airports, schools, and universities to make hybrid flights in the region happen.

Though it is concluded that the project has buy in from many industry stakeholders and Ministry officials, it cannot go forward without the necessary funding. Ampaire is working diligently to locate standard and non-standard funding sources to help Phase 2 of this project go forward.

Commercial scale up offers significant additional scope to the project. New regulations will need to be in place that address the unique needs and challenges related to electrified aircraft. Airports will need to have mature infrastructure and personnel trained to support and maintain an electrified aircraft fleet. Standardized safety procedures need to be developed and communicated to the fire brigades and other first responders regarding new dangers that could result from electrified aircraft mishaps, such as safe ways to shut down the high voltage system. All these elements take time to be understood, developed, agreed upon, and implemented, and it is not too early to begin strategizing. Plans to develop answers to many of these questions are covered in plans for Phase 2.

Appendix A – EASA Regulation Digest & links

SUBPART D: INSTRUMENTS, DATA, EQUIPMENT, SECTION 1 – AEROPLANES, **CAT.IDE.A.285** Flight over water Regulation (EU) 2019/1384

(a) The following aeroplanes shall be equipped with a life-jacket for each person on board or equivalent flotation device for each person on board younger than 24 months, stowed in a position that is readily accessible from the seat or berth of the person for whose use it is provided: (1) landplanes operated over water at a distance of more than 50 NM from the shore or taking off or landing at an aerodrome where the take-off or approach path is so disposed over water that there would be a likelihood of a ditching; and (2) seaplanes operated over water.

(b) Each life-jacket or equivalent individual flotation device shall be equipped with a means of electric illumination for the purpose of facilitating the location of persons.

(c) Seaplanes operated over water shall be equipped with the following: (1) a sea anchor and other equipment necessary to facilitate mooring, anchoring or manoeuvring the seaplane on water, appropriate to its size, mass and handling characteristics; (2) equipment for making the sound signals as prescribed in the International Regulations for Preventing Collisions at Sea, where applicable.

(d) Aeroplanes operated over water at a distance away from land suitable for making an emergency landing, greater than that corresponding to:

(1) 120 minutes at cruising speed or 400 NM, whichever is the lesser, in the case of aeroplanes capable of continuing the flight to an aerodrome with the critical engine(s) becoming inoperative at any point along the route or planned diversions; or

(2) for all other aeroplanes, 30 minutes at cruising speed or 100 NM, whichever is the lesser,

shall be equipped with the equipment specified in (e).

(e) Aeroplanes complying with (d) shall carry the following equipment: (1) life-rafts in sufficient numbers to carry all persons on board, stowed so as to facilitate their ready use in an emergency, and being of sufficient size to accommodate all the survivors in the event of a loss of one raft of the largest rated capacity; (2) a survivor locator light in each life-raft; (3) life-saving equipment to provide the means for sustaining life, as appropriate for the flight to be undertaken; and (4) at least two survival ELTs (ELT(S)).

(f) By 1 January 2019 at the latest, aeroplanes with an MCTOM of more than 27 000 kg and with an MOPSC of more than 19 and all aeroplanes with an MCTOM of more than 45 500 kg shall be fitted with a securely attached underwater locating device that operates at a frequency of 8,8 kHz ± 1 kHz, unless: (1) the aeroplane is operated over routes on which it is at no point at a distance of more than 180 NM from the shore; or (2) the aeroplane is equipped with robust and automatic means to accurately determine, following an accident where the aeroplane is severely damaged, the location of the point of end of flight.

AMC1 SPA.SET-IMC.105(d)(2) SET-IMC operations approval

ED Decision 2017/004/R

FLIGHT PLANNING

(a) The operator should establish flight planning procedures to ensure that the routes and cruising altitudes are selected so as to have a landing site within gliding range.

(b) Notwithstanding (a) above, whenever a landing site is not within gliding range, one or more risk periods may be used for the following operations:

(1) over water;

(2) over hostile environment; or

(3) over congested areas.

Except for the take-off and landing phase, the operator should ensure that when a risk period is planned, there is a possibility to glide to a non-congested area.

The total duration of the risk period per flight **should not exceed 15 min** unless the operator has established, based on a risk assessment carried out for the route concerned, that **the cumulative risk of fatal accident due to an engine failure for this flight remains at an acceptable level** (see GM2 SPA.SET-IMC.105(d)(2)).

Appendix B – FAA Regulation Digest & Links

Note: Any blue underlined font in this section denotes a hyperlink to online content.

91.205 Powered civil aircraft with standard category U.S. airworthiness certificates: Instrument and equipment requirements.

(a) ***General.*** Except as provided in paragraphs (c)(3) and (e) of this section, no person may operate a powered civil aircraft with a standard category U.S. airworthiness certificate in any operation described in paragraphs (b) through (f) of this section unless that aircraft contains the instruments and equipment specified in those paragraphs (or FAA-approved equivalents) for that type of operation, and those instruments and items of equipment are in operable condition.

(b) ***Visual-flight rules (day).*** For VFR flight during the day, the following instruments and equipment are required:

(1) Airspeed indicator.

(2) Altimeter.

(3) Magnetic direction indicator.

(4) Tachometer for each engine.

(5) Oil pressure gauge for each engine using pressure system.

(6) Temperature gauge for each liquid-cooled engine.

(7) Oil temperature gauge for each air-cooled engine.

(8) Manifold pressure gauge for each altitude engine.

(9) Fuel gauge indicating the quantity of fuel in each tank.

(10) Landing gear position indicator, if the aircraft has a retractable landing gear.

(11) For small civil airplanes certificated after March 11, 1996, in accordance with part 23 of this chapter, an approved aviation red or aviation white anticollision light system. In the event of failure of any light of the anticollision light system, operation of the aircraft may continue to a location where repairs or replacement can be made.

(12) If the aircraft is operated for hire over water and beyond power-off gliding distance from shore, approved flotation gear readily available to each occupant and, unless the aircraft is operating under part 121 of this subchapter, at least one pyrotechnic signalling device. As used in this section, “shore” means that area of the land adjacent to the water which is above the high water mark and excludes land areas which are intermittently under water.

(13) An approved safety belt with an approved metal-to-metal latching device, or other approved restraint system for each occupant 2 years of age or older.

(14) For small civil airplanes manufactured after July 18, 1978, an approved shoulder harness or restraint system for each front seat. For small civil airplanes manufactured after December 12, 1986, an approved shoulder harness or restraint system for all seats. Shoulder harnesses installed at flightcrew stations must permit the flightcrew member, when seated and with the safety belt and shoulder harness fastened, to perform all functions necessary for flight operations. For purposes of this paragraph—

(i) The date of manufacture of an airplane is the date the inspection acceptance records reflect that the airplane is complete and meets the FAA-approved type design data; and

(ii) A front seat is a seat located at a flightcrew member station or any seat located alongside such a seat.

(15) An emergency locator transmitter, if required by § 91.207.

(16) [Reserved]

(17) For rotorcraft manufactured after September 16, 1992, a shoulder harness for each seat that meets the requirements of § 27.2 or § 29.2 of this chapter in effect on September 16, 1991.

(c) ***Visual flight rules (night).*** For VFR flight at night, the following instruments and equipment are required:

(1) Instruments and equipment specified in paragraph (b) of this section.

(2) Approved position lights.

(3) An approved aviation red or aviation white anticollision light system on all U.S.-registered civil aircraft. Anticollision light systems initially installed after August 11, 1971, on aircraft for which a type certificate was issued or applied for before August 11, 1971, must at least meet the anticollision light standards of part 23, 25, 27, or 29 of this chapter, as applicable, that were in effect on August 10, 1971, except that the color may be either aviation red or aviation white. In the event of failure of any light of the anticollision light system, operations with the aircraft may be continued to a stop where repairs or replacement can be made.

(4) If the aircraft is operated for hire, one electric landing light.

(5) An adequate source of electrical energy for all installed electrical and radio equipment.

(6) One spare set of fuses, or three spare fuses of each kind required, that are accessible to the pilot in flight.

(d) ***Instrument flight rules.*** For IFR flight, the following instruments and equipment are required:

(1) Instruments and equipment specified in paragraph (b) of this section, and, for night flight, instruments and equipment specified in paragraph (c) of this section.

(2) Two-way radio communication and navigation equipment suitable for the route to be flown.

(3) Gyroscopic rate-of-turn indicator, except on the following aircraft:

(i) Airplanes with a third attitude instrument system usable through flight attitudes of 360 degrees of pitch and roll and installed in accordance with the instrument requirements prescribed in § 121.305(j) of this chapter; and

(ii) Rotorcraft with a third attitude instrument system usable through flight attitudes of ±80 degrees of pitch and ±120 degrees of roll and installed in accordance with § 29.1303(g) of this chapter.

(4) Slip-skid indicator.

(5) Sensitive altimeter adjustable for barometric pressure.

(6) A clock displaying hours, minutes, and seconds with a sweep-second pointer or digital presentation.

(7) Generator or alternator of adequate capacity.

(8) Gyroscopic pitch and bank indicator (artificial horizon).

(9) Gyroscopic direction indicator (directional gyro or equivalent).

(e) ***Flight at and above 24,000 feet MSL (FL 240).*** If VOR navigation equipment is required under paragraph (d)(2) of this section, no person may operate a U.S.-registered civil aircraft within the 50 states and the District of Columbia at or above FL 240 unless that aircraft is equipped with approved DME or a suitable RNAV system. When the DME or RNAV system required by this paragraph fails at and above FL 240, the pilot in command of the aircraft must notify ATC immediately, and then may continue operations at and above FL 240 to the next airport of intended landing where repairs or replacement of the equipment can be made.

(f) ***Category II operations.*** The requirements for Category II operations are the instruments and equipment specified in:

(1) Paragraph (d) of this section; and

(2) Appendix A to this part.

(g) ***Category III operations.*** The instruments and equipment required for Category III operations are specified in paragraph (d) of this section.

(h) ***Night vision goggle operations.*** For night vision goggle operations, the following instruments and equipment must be installed in the aircraft, functioning in a normal manner, and approved for use by the FAA:

(1) Instruments and equipment specified in paragraph (b) of this section, instruments and equipment specified in paragraph (c) of this section;

(2) Night vision goggles;

(3) Interior and exterior aircraft lighting system required for night vision goggle operations;

(4) Two-way radio communications system;

(5) Gyroscopic pitch and bank indicator (artificial horizon);

(6) Generator or alternator of adequate capacity for the required instruments and equipment; and

(7) Radar altimeter.

(i) ***Exclusions.*** Paragraphs (f) and (g) of this section do not apply to operations conducted by a holder of a certificate issued under part 121 or part 135 of this chapter.

FAA Advisory Circular AC 91-70A

13-7. EQUIPMENT.

a. Emergency Equipment Requirements. Single-engine aircraft will carry life rafts when operating more than 100 NM from shore and multiengine aircraft will carry them when operating more than 200 NM from shore. These life rafts will contain at least the following:
   - Pyrotechnic distress signals.
   - Food and water.
   - A VHF survival radio.

Appendix C – Curaçao Regulation Digest & Links

CCAR 8.7.2.2: **GENERAL**

a) No person may operate a single-engine aircraft or an aircraft type certificated for operation by a single-pilot used for revenue passenger carrying operations unless that aircraft is continually operated in daylight, VFR, excluding over the top, and over routes and diversions there that do not permit a safe forced landing to be executed in the event of an engine failure.
   (1) Notwithstanding Subsection 8.7.2.2(e), the Authority may approve single-pilot operations in propeller driven, turbine powered aircraft under IFR, at night, or under IMC for aircraft certificated for a maximum take-off weight of 5,700 kg (12,566 lb) or less and a maximum approved passenger seating configuration of 9 or less, provided it meets the equipment requirements of Part 7.

8.7.2.3 **SINGLE AND MULTI-ENGINE AEROPLANE OPERATIONS**

a) No person may operate a single-engine aircraft in revenue passenger carrying operations unless that aircraft is continually operated in daylight, VFR over such routes and diversions there from that permit a safe forced landing to be executed in the event of an engine failure.

b) No person shall operate single-engine turbine-powered aeroplanes at night and/or in IMC unless the airworthiness certification of the aeroplane is appropriate and acceptable to the Authority and that the overall safety of the operation is consistent with commercial air transportation operations as provided by:
   1) The reliability of the turbine engine;
   2) The operator's maintenance procedures, operating practices, flight dispatch procedures;
   3) Crew training programmes; and
   4) Equipment and additional requirements provided in accordance with paragraph (d)

c) No person shall operate a single-engine turbine-powered aeroplane at night and/or in IMC unless the aeroplane has an engine trend monitoring system, and those aeroplanes for which the individual certificate of airworthiness is first issued on or after 1 January 2005 shall have an automatic trend monitoring system.

8.8.1.30 **SINGLE PILOT OPERATIONS AEROPLANE**

a) An aeroplane shall not be operated under the IFR or night by a single pilot unless approved by the State of the Operator.
b) An aeroplane shall not be operated under IFR or at night by a single pilot unless;
   1) the flight manual does not require a flight crew of more than one;
   2) the aeroplane is propeller driven; turbine powered and complies with Subsection 8.7.2.2 (e)(1),
   3) the maximum approved passenger seating configuration is not more than nine, or the aeroplane is propeller driven, turbine powered and complies with Subsection 8.7.2.2(e)(2) and the maximum approved passenger seating configuration is more than nine;
   4) the maximum certificated take-off mass does not exceed 5,700 kg (12,566 lb);
   5) the aeroplane is equipped as described in Part 7: 7.2.1.4 (c)(3);

  6) the pilot-in-command has satisfied the requirements of experience, training, checking, and recency described in Subsection 8.10.1.41.

c) Notwithstanding (b)(2) and (b)(3) above, the aeroplane shall be operated in compliance with Subsection 8.7.2.2(a).

d) Any exemption for single pilot operations with more than nine passengers shall be authorized by the Authority in the operator's operations specifications, as required by Subsection 8.7.2.2(e)(2).

e) If such operations are to be conducted outside of Curaçao, the Authority shall have an arrangement with the States where the operations will be conducted.

8.8.1.31 SINGLE ENGINE AEROPLANE OPERATIONS

a) Except as provided in (b) and (c) single-engine aeroplanes, shall only be operated in conditions of weather and light, and over such routes and diversions therefrom, that permit a safe forced landing to be executed in the event of engine failure.

b) In approving operations by single-engine turbine-powered aeroplanes, at night and/or in IMC, the State of the Operator shall ensure that the airworthiness certification of the aeroplane is appropriate and that the overall level of safety intended by the provisions of Parts 5 and 8 is provided by;
  1) the reliability of the turbine engine;
  2) the operator's maintenance procedures, operating practices, flight dispatch procedures and crew training programmes; and
  3) equipment, and other requirements provided in accordance with Subsection 8.7,2.3 and IS: 8.7.2.3

c) All single-engine turbine-powered aeroplanes operated at night and for in IMC shall have an engine trend monitoring system, and those aeroplanes for which the individual certificate of airworthiness is first issued on or after 1 January 2005 shall have an automatic trend monitoring system

IS: 8.7.2.3 SINGLE AND MULTI-ENGINE AEROPLANE OPERATIONS

a) In addition to the requirements in outlined under Subsection 8.7.2.3, an AOC holder seeking approval from the Authority to operate single-engine turbine-powered aeroplanes at night and/or in IMC shall comply with the additional requirements of this implementing standard.

b) An AOC holder shall not operate single-engine, turbine-powered aeroplanes at night and/or in IMC unless the following airworthiness and operational requirements have been satisfied by the operator and approved by the Authority. (1) Turbine Engine Reliability (2) Turbine engine reliability shall be shown to have a power loss rate of less than 1 per 100,000 engine hours Note: Power loss in this context is defined as any loss of power, the cause of which may be traced to faulty engine or engine component design or installation, including design or installation of the fuel ancillary or engine control systems.

c) The operator shall be responsible for engine trend monitoring.

d) To minimize the probability of in-flight engine failure, the engine shall be equipped with: (1) An ignition system that activates automatically, or is capable of being operated manually for take-off and landing, and during flight, in visible moisture (2) A magnetic particle detection or equivalent system that monitors the engine, accessories gearbox, and reduction gearbox, and which includes a flight deck caution indication; and (3) An emergency engine power control device that permits continuing operation of the engine through a sufficient power range to safely complete the flight in the event of any reasonably probable failure of the fuel control unit.

e) Systems and Equipment. Single-engine turbine-powered aeroplanes approved to operate at night and/or in IMC shall be equipped with the following systems and equipment intended to ensure continued safe flight and to assist in achieving a safe forced landing after an engine failure, under all allowable operating conditions:
   1) Two separate electrical generating systems, each one capable of supplying all probable combinations of continuous in-flight electrical loads for instruments, equipment and systems required at night and/or in IMC;
   2) A radio altimeter;
   3) An emergency electrical supply system of sufficient capacity and endurance, following loss of all generated power, to as a minimum:

      (i) Maintain the operation of all essential flight instruments, communication and

      (ii) Navigation systems during a descent from the maximum certificated altitude in a glide configuration to the completion of a landing;

      (iii) Lower the flaps and landing gear, if applicable;

      (iv) Provide power to one pitot heater, which must serve an air speed indicator clearly visible to the pilot;

      (v) Provide for operation of the landing light specified in (e)(10) below;

      (vi) Provide for one engine restart, if applicable; and

      (vii) Provide for the operation of the radio altimeter; Part 8 – Operations IMPLEMENTING STANDARDS IS 8-122

   4) Two attitude indicators, powered from independent sources;
   5) A means to provide for at least one attempt at engine re-start;
   6) Airborne weather radar;
   7) A certified area navigation system capable of being programmed with the positions of aerodromes and safe forced landing areas, and providing instantly available track and distance information to those locations;
   8) For passenger operations, passenger seats and mounts which meet dynamically-tested performance standards and which are fitted with a shoulder harness or a safety belt with a diagonal shoulder strap for each passenger seat;
   9) In pressurised aeroplanes, sufficient supplemental oxygen for all occupants for descent following engine failure at the maximum glide performance from the maximum certificated altitude to an altitude at which supplemental oxygen is no longer required;
   10) A landing light that is independent of the landing gear and is capable of adequately illuminating the touchdown area in a night forced landing; and
   11) An engine fire warning system.

f) Minimum Equipment List (MEL). An AOC holder shall develop an MEL approved by the Authority that is appropriate to the type of single-engine turbine-powered aeroplane operated specifying the operating equipment required for night and/or IMC operations, and for day/VMC operations.

g) Aeroplane Flight Manual (AFM) Information. The AFM shall include limitations, procedures, approval status and other information relevant to operations by single-engine turbine-powered aeroplanes at night and/or in IMC.
h) Event Reporting. An AOC holder operating turbine-powered aeroplanes at night and/or in IMC shall report all significant failures, malfunctions or defects to the Authority who in turn will notify the State of Design.
i) Operator Planning. Each AOC holder operating single-engine turbine-powered aeroplanes at night and/or in IMC shall take account of all relevant information in the assessment of intended routes or areas of operations, including the following:
    1) The nature of the terrain to be overflown, including the potential for carrying out a safe forced landing in the event of an engine failure or major malfunction;
    2) Weather information, including seasonal and other adverse meteorological influences that may affect the flight; and
    3) Other criteria and limitations as specified by the Authority.
j) Each AOC holder shall identify aerodromes or safe forced landing areas available for use in the event of engine failure and the position of these shall be programmed into the area navigation system.

Note 1: A ‘safe’ forced landing in this context means a landing in an area at which it can reasonably be expected that it will not lead to serious injury or loss of life, even though the aeroplane may incur extensive damage. Note 2: Operation over routes and in weather conditions that permit a safe forced landing in the event of an engine failure, as specified in Subsection 8.8.1.30 (a) is not required for aeroplanes approved in accordance with Subsection 8.8.1.30 (a)(1). The availability of forced landing areas at all points along a route is not specified for these aeroplanes because of the very high engine reliability, additional systems and operational equipment, procedures and training requirements specified in this implementing standard. IMPLEMENTING STANDARDS Part 8 – Operations IS 8-123

k) Flight Crew Experience, Training and Checking (1) No person may serve and no AOC holder shall use a flight crewmember in single-engine turbine-powered aeroplanes engaged in commercial air transport unless he or she has completed the appropriate flight crewmember training as specified in this Part and approved by the Authority. (2) The AOC holder’s approved flight crew training and checking shall be appropriate to night and/or IMC operations by single engine turbine-powered aeroplanes, covering normal, abnormal and emergency procedures and, in particular, engine failure, including descent to a forced landing in night and/or in IMC conditions.
l) Route Limitations Over Water
    1) An AOC holder shall not conduct over water operations using single-engine turbine-powered aeroplanes operating at night and/or in IMC except in areas of operation or over specific routes identified in the AOC holder’s operation specifications.
    2) No AOC holder may conduct over water operations using single-engine turbine-powered aeroplanes operating at night and/or in IMC except in accordance with procedures approved by the Authority in the AOC holder’s operations manual for over water operations covering flight beyond gliding distance from an area suitable for a safe forced landing/ditching having regard to the characteristics of the aeroplane, seasonal weather influences, including likely sea state and temperature, and the availability of search and rescue services.
m) Operator Certification or Validation. (1) An AOC holder applying for operations specifications granting authorisation to conduct single-engine turbine-powered aeroplane operations at night

and/or in IMC shall demonstrate to the Authority consistent with Part 9 Air Operator Certification & Administration, the ability to conduct operations by single-engine turbine-powered aeroplanes at night and/or in IMC through a certification and approval process specified by the Authority.

Appendix D – Aruba Regulation Digest & Links

AUA-OPS 1.525 General
(a) Except under AUA-OPS 1.526 or where otherwise approved by the Authority, the operator shall not operate a single-engine aeroplane:
(1) at night; or
(2) in Instrument Meteorological Conditions
Note: Limitations on the operation of single-engine aeroplanes, not approved under AUA-OPS 1.526, are covered by AUA-OPS 1.240(d)(6).
(b) The operator shall treat two-engine aeroplanes which do not meet

AUA-OPS 1.526 Operations of Single-engine Turbine-powered Aeroplanes at Night and/or in Instrument Meteorological Conditions (IMC)
(See AUA-OPS 1.842)
(See IEM OPS 1.526)
(Appendix 2 to AUA-OPS 1.940)
(a) The operator may be approved to conduct operations by single-engine turbine-powered aeroplanes at night and/or in IMC, provided that the airworthiness certification of the aeroplane is appropriate and that the overall level of safety is provided by:
(b) the reliability of the turbine engine shall be shown to have a power loss rate of less than 1 per 100 000 engine hours.

Note 1: Power loss in this context is defined as any loss of power, the cause of which may be traced to faulty engine or engine component design or installation, including design or installation of the fuel ancillary or engine control systems.
Note 2: The operator shall be responsible for engine trend monitoring.
(c) the operator's maintenance procedures, operating practices, flight dispatch procedures and crew training programmes; and
(d) equipment as specified in AUA-OPS 1.842
(e) the minimum equipment list shall specify the operating equipment required for night and/or IMC operations, and for day/VMC operations.

(f) The flight manual shall include limitations, procedures, approval status and other information relevant to operations by single-engine turbine-powered aeroplanes at night and/or in IMC.

(g) The operator approved for operations by single-engine turbine-powered aeroplanes at night and/or in IMC shall report all significant failures, malfunctions or defects to the Authority for notification to the State of Design.

Note: As part of the trend monitoring system the Authority will review the safety data and monitor the reliability information so as to be able to take any actions necessary to ensure that the intended safety level is achieved. The Authority will notify major events or trends of particular concern to the appropriate Type Certificate Holder and the State of Design.

(h) Operator route planning shall take account of all relevant information in the assessment of intended routes or areas of operations, including the following:
(1) the nature of the terrain to be overflown, including the potential for carrying out a safe forced landing in the event of an engine failure or major malfunction;
(2) weather information, including seasonal and other adverse meteorological influences that may affect the flight; and
(3) other criteria and limitations as specified by the State of the Operator.
(i) The operator shall identify aerodromes or safe forced landing areas available for use in the event of engine failure, and the position of these shall be programmed into the area navigation system. (See IEM OPS 1.526(i))

Note: A 'safe' forced landing in this context means a landing in an area at which it can reasonably be expected that it will not lead to serious injury or loss of life, even though the aeroplane may incur extensive damage.

AUA-OPS 1.542 En-Route – Single-engine Aeroplanes
(See IEM OPS 1.542)
(a) The operator shall ensure that the aeroplane, in the meteorological conditions expected for the flight, and in the event of engine failure, is capable of reaching a place at which a safe forced landing can be made. For landplanes, a place on land is required, unless otherwise approved by the Authority. (See AMC OPS 1.542(a).)
(b) When showing compliance with sub-paragraph (a) above:
(1) The aeroplane must not be assumed to be flying, with the engine operating within the maximum continuous power conditions specified, at an altitude exceeding that at which the rate of climb equals 300 ft per minute; and

(2) The assumed en-route gradient shall be the gross gradient of descent increased by a gradient of 0·5%.

AUA-OPS 1.842 Additional Requirements for Operations of Single-engine Turbine-powered Aeroplanes at Night and/or in Instrument Meteorological Conditions (IMC)
(See AUA-OPS 1.526)
(See IEM OPS 1.526)
(a) All single-engine turbine-powered aeroplanes operated at night and/or in IMC shall have an engine trend monitoring system, and those aeroplanes for which the individual certificate of airworthiness is first issued on or after 01 January 2005 shall have an automatic trend monitoring.

(b) To minimize the probability of in-flight engine failure, the engine shall be equipped with:

(1) an ignition system that activates automatically, or is capable of being operated manually, for take-off and landing, and during flight, in visible moisture;
(2) a magnetic particle detection or equivalent system that monitors the engine, accessories gearbox, and reduction gearbox, and which includes a flight deck caution indication; and
(3) an emergency engine power control device that permits continuing operation of the engine through a sufficient power range to safely complete the flight in the event of any reasonably probable failure of the fuel control unit.

(c) Single-engine turbine-powered aeroplanes approved to operate at night and/or in IMC shall be equipped with the following systems and equipment intended to ensure continued safe flight and to assist in achieving a safe forced landing after an engine failure, under all allowable operating conditions:

(1) two separate electrical generating systems, each one capable of supplying all probable combinations of continuous in-flight electrical loads for instruments, equipment and systems required at night and/or in IMC;

(2) a radio altimeter;
(3) an emergency electrical supply system of sufficient capacity and endurance, following loss of all generated power, to as a minimum:
(i) maintain the operation of all essential flight instruments, communication and navigation systems during a descent from the maximum certificated altitude in a glide configuration to the completion of a landing;
(iii) lower the flaps and landing gear, if applicable;

(iv) provide power to one pitot heater, which must serve an air speed indicator clearly visible to the pilot;

(v) provide for operation of the landing light;

(vi) provide for one engine restart, if applicable; and

(vi) provide for the operation of the radio altimeter;
(4) two attitude indicators, powered from independent sources;
(5) a means to provide for at least one attempt at engine start;
(6) airborne weather radar;
(7) a certified area navigation system capable of being programmed with the positions of aerodromes and safe forced landing areas, and providing instantly available track and distance information to those locations;
(8) for passenger operations, passenger seats and mounts which meet dynamically-tested performance standards and which are fitted with a shoulder harness or a safety belt with a diagonal shoulder strap for each passenger seat;
(9) in pressurised aeroplanes, sufficient supplemental oxygen for all occupants for descent following engine failure at the maximum glide performance from the maximum certificated altitude to an altitude at which supplemental oxygen is no longer required;
(10) a landing light that is independent of the landing gear and is capable of adequately illuminating the touchdown area in a night forced landing; and

(11) an engine fire warning system.

SECTION 2 - ADVISORY CIRCULARS (AC), ACCEPTABLE MEANS OF COMPLIANCE (AMC), INTERPRETATIVE/EXPLANATORY MATERIAL (IEM)

AMC/IEM H
PERFORMANCE CLASS B

IEM OPS 1.526
S/E Operations at Night or in IMC
1. Purpose and scope

The purpose of this IEM is to give additional guidance on the airworthiness and operational requirements described in AUA-OPS 1.526 and AUA-OPS 1.842, which have been designed to meet the overall level of safety intended for approved operations by single-engine turbine-powered aeroplanes at night and/or in IMC.

2. Turbine engine reliability

2.1 The power loss rate required should be established as likely to be met based on data from commercial operations supplemented by available data from private operations in similar theatres of operation. A minimum amount of service experience is needed on which to base the judgment, and this should include at least 20 000 hours on the actual aeroplane/engine combination unless additional testing has been carried out or experience on sufficiently similar variants of the engine is available.

2.2 In assessing turbine engine reliability, evidence should be derived from a world fleet database covering as large a sample as possible of operations considered to be representative, compiled by the manufacturers and reviewed with the States of Design and of the Operator. Since flight hour reporting is not mandatory for many types of operators, appropriate statistical estimates may be used to develop the engine reliability data. Data for individual operators approved for these operations including trend monitoring and event reports should also be monitored and reviewed by the State of the Operator to ensure that there is no indication that the operator's experience is unsatisfactory.

2.2.1 Engine trend monitoring should include the following:

a. an oil consumption monitoring programme based on manufacturers' recommendations; and

b. an engine condition monitoring programme describing the parameters to be monitored, the method of data collection and the corrective action process; this should be based on the manufacturer's recommendations. The monitoring is intended to detect turbine engine deterioration at an early stage to allow for corrective action before safe operation is affected.

2.2.2 A reliability programme should be established covering the engine and associated systems. The engine programme should include engine hours flown in the period and the in-flight shutdown rate for all causes and the unscheduled engine removal rate, both on a 12-month moving average basis. The event reporting process should cover all items relevant to the ability to operate safely at night and/or in IMC. The data should be available for use by the operator, the Type Certificate Holder and the Authority so as to establish that the intended reliability levels are being achieved. Any sustained adverse trend should result in an immediate evaluation by the operator in consultation with the Authority and manufacturer with a view to determining actions to restore the intended safety level. The operator should develop a parts control programme with support from the manufacturer that ensures that the proper parts and configuration are maintained for single-engine turbine-powered aeroplanes approved to conduct these operations.

The programme includes verification that parts placed on an approved single-engine turbine-powered aeroplane during parts borrowing or pooling arrangements, as well as those parts used after repair or overhaul, maintain the necessary configuration of that aeroplane for operations approved in accordance with AUA-OPS 1.526.

2.3 Power loss rate should be determined as a moving average over a specified period (e.g. a 12-month moving average if the sample is large). Power loss rate, rather than in-flight shut-down rate, has been used as it is considered to be more appropriate for a single-engine aeroplane. If a failure occurs on a multi-engine aeroplane that causes a major, but not total, loss of power on one engine, it is likely that the engine will be shut down as positive engine-out performance is still available, whereas on a single-engine aeroplane it may well be decided to make use of the residual power to stretch the glide distance.

2.4 The actual period selected should reflect the global utilization and the relevance of the experience included

(e.g. early data may not be relevant due to subsequent mandatory modifications which affected the power loss rate). After the introduction of a new engine variant and whilst global utilization is relatively low, the total available experience may have to be used to try to achieve a statistically meaningful average.

3. Operations Manual

The Operations Manual should include all necessary information relevant to operations by single-engine turbine-powered aeroplanes at night and/or in IMC. This should include all of the additional equipment, procedures and training required for such operations, route and/or area of operation and aerodrome information (including and operating minima).

4. Operator certification or validation

The certification or validation process specified by the Authority will ensure the adequacy of the operator’s procedures for normal, abnormal and emergency operations, including actions following engine, systems or equipment failures. In addition to the normal requirements for operator certification or validation, the following items should be addressed in relation to operations by single-engine turbine-powered aeroplanes:

a. proof of the achieved engine reliability of the aeroplane engine combination;

b. specific and appropriate training and checking procedures including those to cover engine failure/ malfunction on the ground, after take-off and enroute and descend to a forced landing from the normal cruising altitude;

c. a maintenance programme which is extended to address the equipment and systems;

d. an MEL modified to address the equipment and systems necessary for operations at night and/or in IMC;

e. planning and operating minima appropriate to the operations at night and/or in IMC;

f. departure and arrival procedures and any route limitations;

g. pilot qualifications and experience; and

h. the Operations Manual, including limitations, emergency procedures, approved routes or areas of operation, the MEL and normal procedures related to the equipment.

5. Operational and maintenance programme requirements

5.1 Approval to undertake operations by single-engine turbine-powered aeroplanes at night and/or in IMC specified in an air operator certificate or equivalent document should include the particular airframe/engine combinations, including the current type design standard for such operations, the specific aeroplanes approved, and the areas or routes of such operations.

5.2 The operator’s maintenance control manual should include a statement of certification of the additional equipment required, and of the maintenance and reliability programme for such equipment, including the engine.

6. Route limitations over water

6.1 Operators of single-engine turbine-powered aeroplanes carrying out operations at night and/or in IMC should make an assessment of route limitations over water. The distance that the aeroplane may be operated from a land mass suitable for a safe forced landing should be determined. This equates to the glide distance from the cruise altitude to the safe forced landing area following engine failure, assuming still air conditions. States may add to this an additional distance taking into account the likely prevailing

conditions and type of operation. This should take into account the likely sea conditions, the survival equipment carried, the achieved engine reliability and the search and rescue services available.
6.2 Any additional distance allowed beyond the glide distance should not exceed a distance equivalent to 15 minutes at the aeroplane's normal cruise speed.

IEM OPS 1.526(i)
S/E operations - Forced Landing Areas

Operation over routes and in weather conditions that permit a safe forced landing in the event of an engine failure, is not required for aeroplanes approved in accordance with AUA-OPS 1.526. The availability of forced landing areas at all points along a route is not specified for these aeroplanes because of

IEM OPS 1.542
En-route – Single-engine Aeroplanes
See AUA-OPS 1.542

1. In the event of an engine failure, single-engine aeroplanes have to rely on gliding to a point suitable for a safe forced landing. Such a procedure is clearly incompatible with flight above a cloud layer which extends below the relevant minimum safe altitude.
2. Operators should first increase the scheduled engine-inoperative gliding performance data by 0·5% gradient when verifying the en-route clearance of obstacles and the ability to reach a suitable place for a forced landing.
3. The altitude at which the rate of climb equals 300 ft per minute is not a restriction on the maximum cruising altitude at which the aeroplane can fly in practice, it is merely the maximum altitude from which the engine-inoperative procedure can be planned to start.

AMC OPS 1.542(a)
En-Route - Single-engine Aeroplanes
See AUA-OPS 1.542(a)

AUA-OPS 1.542(a) requires the operator to ensure that in the event of an engine failure, the aeroplane should be capable of reaching a point from which a successful forced landing can be made. Unless otherwise specified by the Authority, this point should be 1000ft above the intended landing area.

Note1: AMC OPS 1.245(a) discusses approaches related to multiple turbine engine aircraft that may contain acceptable processes and methods for substantiating an alleviation to the standard single-engined operational limitations, for Ampaire's hybrid-electric propulsion based hybrid caravan aircraft.

Note2: IEM OPS 1.526 (S/E Operations at Night or in IMC) details the process for establishing acceptance by Aruba CAA of S/E Operations at Night or in IMC, and overwater

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5.1.2 Except as provided in 5.4, single-engine aeroplanes shall only be operated in conditions of weather and light, and over such routes and diversions therefrom, that permit a safe forced landing to be executed in the event of engine failure.

5.4 ADDITIONAL REQUIREMENTS FOR OPERATIONS OF SINGLE-ENGINE TURBINE-POWERED AEROPLANES AT NIGHT AND/OR IN INSTRUMENT METEOROLOGICAL CONDITIONS (IMC)
5.4.1 In approving operations by single-engine turbine-powered aeroplanes at night and/or in IMC, the State of the Operator shall ensure that the airworthiness certification of the aeroplane is appropriate and that the overall level of safety intended by the provisions of Annexes 6 and 8 is provided by:
a) the reliability of the turbine engine;
b) the operator's maintenance procedures, operating practices, flight dispatch procedures and crew training programmes; and
c) equipment and other requirements provided in accordance with Appendix 3.
5.4.2 All single-engine turbine-powered aeroplanes operated at night and/or in IMC shall have an engine trend monitoring system, and those aeroplanes for which the individual certificate of airworthiness is first issued on or after
1 January 2005 shall have an automatic trend monitoring system.

APPENDIX 3. ADDITIONAL REQUIREMENTS FOR APPROVED OPERATIONS BY SINGLE-ENGINE TURBINE-POWERED AEROPLANES AT NIGHT AND/OR IN INSTRUMENT METEOROLOGICAL CONDITIONS (IMC)

(*Chapter 5, 5.4.1, refers*)
Airworthiness and operational requirements provided in accordance with Chapter 5, 5.4.1, shall satisfy the following:

1. TURBINE ENGINE RELIABILITY

1.1 Turbine engine reliability shall be shown to have a power loss rate of less than 1 per 100 000 engine hours.
Note.— Power loss in this context is defined as any loss of power, the cause of which may be traced to faulty engine or engine component design or installation, including design or installation of the fuel ancillary or engine control systems. (See Attachment G.)

1.2 The operator shall be responsible for engine trend monitoring.

1.3 To minimize the probability of in-flight engine failure, the engine shall be equipped with:
a) an ignition system that activates automatically, or is capable of being operated manually, for take-off and landing, and during flight, in visible moisture;
b) a magnetic particle detection or equivalent system that monitors the engine, accessories gearbox, and reduction gearbox, and which includes a flight deck caution indication; and
c) an emergency engine power control device that permits continuing operation of the engine through a sufficient power range to safely complete the flight in the event of any reasonably probable failure of the fuel control unit.

2. SYSTEMS AND EQUIPMENT

Single-engine turbine-powered aeroplanes approved to operate at night and/or in IMC shall be equipped with the following systems and equipment intended to ensure continued safe flight and to assist in achieving a safe forced landing after an engine failure, under all allowable operating conditions:

a) two separate electrical generating systems, each one capable of supplying all probable combinations of continuous

in-flight electrical loads for instruments, equipment and systems required at night and/or in IMC;

b) a radio altimeter;

c) an emergency electrical supply system of sufficient capacity and endurance, following loss of all generated power, to as a minimum:

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1) maintain the operation of all essential flight instruments, communication and navigation systems during a descent from the maximum certificated altitude in a glide configuration to the completion of a landing;

2) lower the flaps and landing gear, if applicable;

3) provide power to one pitot heater, which must serve an air speed indicator clearly visible to the pilot;

4) provide for operation of the landing light specified in 2 j);

5) provide for one engine restart, if applicable; and

6) provide for the operation of the radio altimeter;

d) two attitude indicators, powered from independent sources;

e) a means to provide for at least one attempt at engine re-start;

f) airborne weather radar;

g) a certified area navigation system capable of being programmed with the positions of aerodromes and safe forced landing areas, and providing instantly available track and distance information to those locations;

h) for passenger operations, passenger seats and mounts which meet dynamically-tested performance standards and

which are fitted with a shoulder harness or a safety belt with a diagonal shoulder strap for each passenger seat;

i) in pressurized aeroplanes, sufficient supplemental oxygen for all occupants for descent following engine failure at the maximum glide performance from the maximum certificated altitude to an altitude at which supplemental oxygen is no longer required;

j) a landing light that is independent of the landing gear and is capable of adequately illuminating the touchdown area

in a night forced landing; and

k) an engine fire warning system.

3. MINIMUM EQUIPMENT LIST

The State of the Operator shall require the minimum equipment list of the operator approved in accordance with Chapter 5, 5.4 to specify the operating equipment required for night and/or IMC operations, and for day/VMC operations.

4. FLIGHT MANUAL INFORMATION

The flight manual shall include limitations, procedures, approval status and other information relevant to operations by single-engine turbine-powered aeroplanes at night and/or in IMC.

5. EVENT REPORTING

5.1 The operator approved for operations by single-engine turbine-powered aeroplanes at night and/or in IMC shall report all significant failures, malfunctions or defects to the State of the Operator who in turn will notify the State of Design.

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5.2 The State of the Operator shall review the safety data and monitor the reliability information so as to be able to take any actions necessary to ensure that the intended safety level is achieved. The State of the Operator will notify major events or trends of particular concern to the appropriate Type Certificate Holder and the State of Design.

6. OPERATOR PLANNING

6.1 Operator route planning shall take account of all relevant information in the assessment of intended routes or areas
of operations, including the following:
a) the nature of the terrain to be overflown, including the potential for carrying out a safe forced landing in the event of an engine failure or major malfunction;
b) weather information, including seasonal and other adverse meteorological influences that may affect the flight; and
c) other criteria and limitations as specified by the State of the Operator.

6.2 The operator shall identify aerodromes or safe forced landing areas available for use in the event of engine failure,
and the position of these shall be programmed into the area navigation system.
Note 1: A 'safe' forced landing in this context means a landing in an area at which it can reasonably be expected that it will not lead to serious injury or loss of life, even though the aeroplane may incur extensive damage.
Note 2: Operation over routes and in weather conditions that permit a safe forced landing in the event of an engine failure, as specified in Chapter 5, 5.1.2, is not required by Appendix 3, 6.1 and 6.2 for aeroplanes approved in accordance with Chapter 5, 5.4. The availability of forced landing areas at all points along a route is not specified for these aeroplanes because of the very high engine reliability, additional systems and operational equipment, procedures and training requirements specified in this Appendix.

7. FLIGHT CREW EXPERIENCE, TRAINING AND CHECKING

7.1 The State of the Operator shall prescribe the minimum flight crew experience required for night/IMC operations by single-engine turbine-powered aeroplanes.

7.2 The operator's flight crew training and checking shall be appropriate to night and/or IMC operations by single engine turbine-powered aeroplanes, covering normal, abnormal and emergency procedures and, in particular, engine failure, including descent to a forced landing in night and/or in IMC conditions.

8. ROUTE LIMITATIONS OVER WATER
The State of the Operator shall apply route limitation criteria for single-engine turbine-powered aeroplanes operating at night and/or in IMC on over water operations if beyond gliding distance from an area suitable for a safe forced landing/ditching having regard to the characteristics of the aeroplane, seasonal weather influences, including likely sea state and temperature, and the availability of search and rescue services.

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9. OPERATOR CERTIFICATION OR VALIDATION
The operator shall demonstrate the ability to conduct operations by single-engine turbine-powered aeroplanes at night and/or in IMC through a certification and approval process specified by the State of the Operator.
Note.— Guidance on the airworthiness and operational requirements is contained in Attachment G.

3.3 Provisions that require an approval

The following provisions require or encourage approval by specified States:
h) Additional requirements for operations of single- single-engine turbine-powered aeroplanes at night and/or in instrument meteorological conditions (IMC) (5.4.1);

3.4 Provisions that require a technical evaluation

Other provisions in Annex 6, Part I, require the State to have made a technical evaluation:
Single-engine operations
cc) turbine engine reliability for approved operations by single-engine turbine-powered aeroplanes at night and/or in instrument meteorological conditions (IMC) (Appendix 3, 1.1);
(jj) route limitations over water (Appendix 3, 8);

ATTACHMENT G. ADDITIONAL GUIDANCE FOR APPROVED OPERATIONS BY SINGLE-ENGINE TURBINE-POWERED AEROPLANES AT NIGHT AND/OR IN INSTRUMENT METEOROLOGICAL CONDITIONS (IMC)

Supplementary to Chapter 5, 5.4 and Appendix 3

1. PURPOSE AND SCOPE

The purpose of this attachment is to give additional guidance on the airworthiness and operational requirements described in Chapter 5, 5.4 and Appendix 3, which have been designed to meet the overall level of safety intended for approved operations by single-engine turbine-powered aeroplanes at night and/or in IMC.

2. TURBINE ENGINE RELIABILITY

2.1 The power loss rate required in Chapter 5, 5.4.1 and Appendix 3 should be established as likely to be met based on data from commercial operations supplemented by available data from private operations in similar theatres of operation. A minimum amount of service experience is needed on which to base the judgment, and this should include at least 20 000 hours on the actual aeroplane/engine combination unless additional testing has been carried out or experience on sufficiently similar variants of the engine is available.

2.2 In assessing turbine engine reliability, evidence should be derived from a world fleet database covering as large a sample as possible of operations considered to be representative, compiled by the manufacturers and reviewed with the States of Design and of the Operator. Since flight hour reporting is not mandatory for many types of operators, appropriate statistical estimates may be used to develop the engine reliability data. Data for individual operators approved for these operations including trend monitoring and event reports should also be monitored and reviewed by the State of the Operator to ensure that there is no indication that the operator’s experience is unsatisfactory.

2.2.1 Engine trend monitoring should include the following:
a) an oil consumption monitoring programme based on manufacturers’ recommendations; and
b) an engine condition monitoring programme describing the parameters to be monitored, the method of data collection and the corrective action process; this should be based on the manufacturer’s recommendations. The monitoring is intended to detect turbine engine deterioration at an early stage to allow for corrective action before safe operation is affected.

2.2.2 A reliability programme should be established covering the engine and associated systems. The engine programme should include engine hours flown in the period and the in-flight shutdown rate for all causes and the unscheduled engine removal rate, both on a 12-month moving average basis. The event reporting process should cover all items relevant to the ability to operate safely at night and/or in IMC. The data should be available for use by the operator, the Type Certificate Holder and the State so as to establish that the intended reliability levels are being achieved. Any sustained adverse trend should result in an immediate evaluation by the operator in consultation with the State and manufacturer with a view to determining actions to restore the intended safety level. The operator should develop a parts control programme with support from the manufacturer that ensures that the proper parts and configuration are maintained for single-engine turbine powered aeroplanes approved to conduct these operations. The programme includes verification that parts placed on an approved single-engine turbine-powered aeroplane during parts borrowing or pooling arrangements, as well as those parts used after repair or overhaul, maintain the necessary configuration of that aeroplane for operations approved in accordance with Chapter 5, 5.4.

2.3 Power loss rate should be determined as a moving average over a specified period (e.g. a 12-month moving average
if the sample is large). Power loss rate, rather than in-flight shut-down rate, has been used as it is considered to be more appropriate for a single-engine aeroplane. If a failure occurs on a multi-engine aeroplane that causes a major, but not total, loss of power on one engine, it is likely that the engine will be shut down as positive engine-out performance is still available, whereas on a single-engine aeroplane it may well be decided to make use of the residual power to stretch the glide distance.

2.4 The actual period selected should reflect the global utilization and the relevance of the experience included
(e.g. early data may not be relevant due to subsequent mandatory modifications which affected the power loss rate). After the introduction of a new engine variant and whilst global utilization is relatively low, the total available experience may have to be used to try to achieve a statistically meaningful average.

3. OPERATIONS MANUAL

The operations manual should include all necessary information relevant to operations by single-engine turbine-powered aeroplanes at night and/or in IMC. This should include all of the additional equipment, procedures and training required for such operations, route and/or area of operation and aerodrome information (including planning and operating minima).

4. OPERATOR CERTIFICATION OR VALIDATION

The certification or validation process specified by the State of the Operator should ensure the adequacy of the operator's procedures for normal, abnormal and emergency operations, including actions following engine, systems or equipment failures. In addition to the normal requirements for operator certification or validation, the following items should be addressed in relation to operations by single-engine turbine-powered aeroplanes:

a) proof of the achieved engine reliability of the aeroplane engine combination (see Appendix 3, paragraph 1);
b) specific and appropriate training and checking procedures including those to cover engine failure/malfunction on the ground, after take-off and en-route and descend to a forced landing from the normal cruising altitude;
c) a maintenance programme which is extended to address the equipment and systems referred to in Appendix 3, paragraph 2;
d) an MEL modified to address the equipment and systems necessary for operations at night and/or in IMC;
e) planning and operating minima appropriate to the operations at night and/or in IMC;
f) departure and arrival procedures and any route limitations;
g) pilot qualifications and experience; and
h) the operations manual, including limitations, emergency procedures, approved routes or areas of operation, the MEL and normal procedures related to the equipment referred to in Appendix 3, paragraph 2.

5. OPERATIONAL AND MAINTENANCE PROGRAMME REQUIREMENTS

5.1 Approval to undertake operations by single-engine turbine-powered aeroplanes at night and/or in IMC specified in an air operator certificate or equivalent document should include the particular airframe/engine combinations, including the current type design standard for such operations, the specific aeroplanes approved, and the areas or routes of such operations.

5.2 The operator's maintenance control manual should include a statement of certification of the additional equipment
required, and of the maintenance and reliability programme for such equipment, including the engine.

6. ROUTE LIMITATIONS OVER WATER

6.1 Operators of single-engine turbine-powered aeroplanes carrying out operations at night and/or in IMC should make an assessment of route limitations over water. The distance that the aeroplane may be operated from a land mass suitable for a safe forced landing should be determined. This equates to the glide distance from the cruise altitude to the safe forced landing area following engine failure, assuming still air conditions. States may add to this an additional distance taking into account the likely prevailing conditions and type of operation. This should take into account the likely sea conditions, the survival equipment carried, the achieved engine reliability and the search and rescue services available.

6.2 Any additional distance allowed beyond the glide distance should not exceed a distance equivalent to 15 minutes at the aeroplane's normal cruise speed.

6.5 ALL AEROPLANES ON FLIGHTS OVER WATER

6.5.2 Landplanes

6.5.2.1 Landplanes shall carry the equipment prescribed in 6.5.2.2:
a) when flying over water and at a distance of more than 93 km (50 NM) away from the shore, in the case of landplanes operated in accordance with 5.2.9 or 5.2.10;
b) when flying en route over water beyond gliding distance from the shore, in the case of all other landplanes; and
c) when taking off or landing at an aerodrome where, in the opinion of the State of the Operator, the take-off or approach path is so disposed over water that in the event of a mishap there would be a likelihood of a ditching.
6.5.2.2 The equipment referred to in 6.5.2.1 shall comprise one life jacket or equivalent individual flotation device for
each person on board, stowed in a position easily accessible from the seat or berth of the person for whose use it is provided.
Note.— "Landplanes" includes amphibians operated as landplanes.

6.5.3 All aeroplanes on long-range over-water flights

6.5.3.1 In addition to the equipment prescribed in 6.5.1 or 6.5.2 whichever is applicable, the following equipment shall be installed in all aeroplanes when used over routes on which the aeroplane may be over water and at more than a distance corresponding to 120 minutes at cruising speed or 740 km (400 NM), whichever is the lesser, away from land suitable for making an emergency landing in the case of aircraft operated in accordance with 5.2.9 or 5.2.10, and 30 minutes or 185 km (100 NM), whichever is the lesser, for all other aeroplanes:
a) life-saving rafts in sufficient numbers to carry all persons on board, stowed so as to facilitate their ready use in emergency, provided with such life-saving equipment including means of sustaining life as is appropriate to the flight to be undertaken;

b) equipment for making the pyrotechnical distress signals described in Annex 2; and
c) at the earliest practicable date, but not later than 1 January 2018, on all aeroplanes of a maximum certificated takeoff mass of over 27 000 kg, a securely attached underwater locating device operating at a frequency of 8.8 kHz. This automatically activated underwater locating device shall operate for a minimum of 30 days and shall not be installed in wings or empennage.
Note.— Underwater locator beacon (ULB) performance requirements are as contained in the SAE AS6254, Minimum Performance Standard for Low Frequency Underwater Locating Devices (Acoustic) (Self-Powered)*, or equivalent documents.*

6.5.3.2 Each life jacket and equivalent individual flotation device, when carried in accordance with 6.5.1 a), 6.5.2.1 and 6.5.2.2, shall be equipped with a means of electric illumination for the purpose of facilitating the location of persons, except where the requirement of 6.5.2.1 c) is met by the provision of individual flotation devices other than life jackets.

8. ROUTE LIMITATIONS OVER WATER

The State of the Operator shall apply route limitation criteria for single-engine turbine-powered aeroplanes operating at night and/or in IMC on over water operations if beyond gliding distance from an area suitable for a safe forced landing/ditching having regard to the characteristics of the aeroplane, seasonal weather influences, including likely sea state and temperature, and the availability of search and rescue services.