THE CHALLENGES

OF COMPLEX AIRCRAFT OPERATIONS

ON AFRICAN UNPAVED AIRSTRIPS

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	CONTENTS	Page
	NOTICES	03
1	Abstract	04 - 05
2	Introduction	06
3	Regulatory framework and aerodrome certification requirements	06 - 07
3.1	ICAO Aerodrome Reference Codes	07
3.1.1	Definition	07
3.1.2	Description	07 - 08
3.1.3	Airstrip Width	08
3.1.4	Aircraft Characteristics	09
3.2	Rescue and Fire Fighting Services	10
3.2.1	Background	10
3.2.2	Capacity	10 - 11
3.2.3	Downgraded Fire Fighting / Rescue Equipment	11
4	Complex Vs. Non-Complex Aircraft	12
4.1	Definition of Complex Aircraft	12
5	Complex Aircraft operational environment	12
6	Runway / Airstrip pavement surface types	13
6.1	Definitions	13
6.2	The various surface types	13
6.2.1	Macadam	13
6.2.2	Gravel Airstrip	14
6.2.3	Flexible Pavement	14
6.2.4	Rigid Pavement	15
6.2.5	Seal Coat	15
6.2.6	Slurry Seal	16
7	Operations on unpaved airstrips	16
7.1	Description	16
7.1.1	Definition of ACN - PCN	17
7.2	Weather and wear effects on unpaved airstrips	17
7.3	Reactionary effects of rainy season on Customer’s unpaved airstrip operations	17 - 18
7.4	Effects of unpaved airstrips on aircraft performance	19
7.5	Aircraft protection	19
7.6	Aircraft certification	19
7.6.1	ATR Special Operations procedures – DRY unpaved airstrips	20
7.6.2	ATR Special Operations procedures - WET and contaminated gravel airstrips	21
7.6.3	ATR Special Operations procedures – Narrow runways	21
8	Aircraft damage from operations on untreated unpaved airstrips	21 - 22
8.1	Gravel kits no longer prevent aircraft damage from gravel airstrips	23 - 26
9	Aircraft maintenance costs and maintenance reserves	27
9.1	Maintenance costs	28
9.2	Maintenance reserves	29
9.3	Airworthiness limitations for ATR42-500 operations on unpaved airstrips (MOD 5038)	29
10	Example of aircraft certification process unpaved airstrips	30 - 31
11	Example of unpaved runway treated with engineered base stabilizer	32 - 33
12	ATR 42-500 performance analysis Ouagadougou - Customer Airstrip - Ouagadougou	34 - 41
13	CONCLUSION	42
14	FINDINGS	42 - 44
14	RECOMMENDATIONS	44

NOTICES

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1. ABSTRACT

A runway/airstrip is an essential element of any airport/airfield, and it significantly influences the safety of an aircraft that uses it. A typical flight includes various phases, but landings and take-offs are sconsidered as the most crucial phases of the flight. An improper landing or take-off may result in serious implications for safety of the aircraft and its occupants, if the runway /airstrip condition is compromised.

An aircraft imposes a tremendous load on a runway/airstrip pavement during landing phase that causes deflection of the pavement. Consequently, the airstrip/airstrip design and performance requirements are largely affected by the potential deflection. A critical review of the relevant literature indicates that the study of aircraft-airstrip interaction has been a challenging problem for runway/airstrip designers, airport/airfield operators, and researchers.

As a major hands-on player since 2005 on the Air Operations Management scene, Euro Ops has gained considerable expertise in managing long-term fixed and rotable wing air transportation contracts on behalf of Non-Governmental Organizations (NGO) in hostile African environments such as Sudan, South Sudan, Mali, Burkina Faso and Central African Republic.

While all of the airstrips initially flown to on behalf of the United Nations (UN) with up to 3 Boeing MD-83 aircraft were paved, the missions were redefined by the UN starting 2015, and included the use of smaller modules capable of operating on unpaved airstrips from time to time. These new specifications led to the introduction of smaller ATR72-500 modules on behalf of UNSMIS (United Nations – Sudan). UMSMISS (United Nations – South Sudan), UNAMID (United Nations – Sudan) and MINUSMA (United Nations – Mali)

Since such new assignments now included some operations on unpaved gravel strips, the operator proceeded with the installation of additional fuselage protections on 3 of its ATR72-500 fleet. Such devices are offered by the manufacturer ATR as a kit and are validated by a Service Bulletin. Their purpose is to offer a reduction of the damage risks on the main landing gear fairings and doors as well as under fuselage, forward of the main landing gear belly fairings.

In early 2020, Euro Ops has been approached by a helicopter operator in Burkina Faso in order to evaluate alternative fixed wing air transport solutions for staff transportation on behalf of a multinational mining Company operating in Burkina Faso (Customer). The specifications of the mission were compatible with the overall performance of the De Havilland/Viking Twin Otter 300/400, a rugged non-complex aircraft with a capacity of 19 seats, capable of operating all year round from the Customer's home base located in the capital Ouagadougou to a short private laterite airstrip located on the grounds of the mining concession.

In February 2022, Euro Ops teamed up with Swiss utility aviation specialist Zimex and Burkinabe carrier Air Sarada to jointly respond to a tender issued by the Customer for the provision of long-term air transport services between Ouagadougou and the private mining concession, as well as some flights to the nearby public aerodrome of Fada N'Gourma. A significant increase of the weekly passenger forecasted loads has led the Customer to require higher a capacity aircraft than the 19-seats offered by the Twin Otter 300, of which two units of Zimex currently perform at least one daily rotation each between the capital Ouagadougou and the Customer's unpaved airstrip.

The Customer's invitation to tender documents indicate that the private laterite airstrip's dimensions have meanwhile been increased to 1'342 m long and 32 meters wide, allowing, to operate a module up to 50 passengers (ATR42-500 or Dash8-300)

A feasibility study issued the Burkinabe Civil Aviation Authorities on 19.03.2019 for the construction of Customer's airstrip on the premises his mining concession was based on the performance and technical characteristics of a Cessna 208B Caravan, a non-complex single engine turboprop with a capacity of 9 to 13 passengers, depending on the configuration.

According to an official airstrip approval document issued by the Burkinabe Civil Aviation Authorities on 25.09.2020, the length of the Customer's private airstrip is only 1'142 meters long and the airfield holds the International Civil Aviation Organization (ICAO) Airfield Classification Reference Code 1B.

Such airfield reference code allows operations of non-complex aircraft up to the Twin Otter 300 / 400 but is not suitable for the operation of a complex aircraft such as the ATR42-500 or the Dash 8-300. Furthermore, neither the ATR42-500 nor its competitor the Dash8-300 are certified to operate on unpaved laterite airstrips in WET conditions, meaning that under the current state of the airstrip surface, safe and reliable operations cannot be guaranteed all year long, in particular during the entire rainy season.

Euro Ops has approached ATR in order to obtain professional advice and documentation with regard to the operational performances of the ATR products on the Customer's unpaved airstrip. It has later been decided to concentrate the evaluation on the ATR42-500, which is the model that corresponds most closely to the requirements of the specifications of the call for tender.

In the meantime, ATR, Zimex and Euro Ops have agreed to team up in a Working Group (Working Group) in order share their respective ranges of resources and experience in order to evaluate all aspects of the operations of complex aircraft on unpaved airstrips. An additional company has recently joined the Working Group: Soil Solutions, a world leader in the airstrip pavement upgrades which provides sustainable turnkey solutions using innovative technology.

The Working Group is now made up of 4 complementary entities, i.e.:

- ATR, an aircraft manufacturer that provides all information and support related to the performance evaluation of the ATR42-500 in particular with regard to operations on unpaved airstrips,

- ZIMEX, a European aircraft operator that provides more than 5 decades of hands-on experience of utility transportation in African remote areas as well an ATR42/72 passenger and cargo operator.

- EURO OPS, an operations management specialist that provides 17 years of hands-on experience in managing long-term contracts on behalf of NGO's in challenging environments,

- SOIL SOLUTIONS, an Engineering Company that provides sustainable unpaved airstrip upgrade consulting and solutions

ATR72-500 Registrations: EC-KKQ and EC-KUL on the ground in Gao, Mali - December 2021

2. Introduction

Undeniably one of the greatest advantages provided by dedicated air transportation services to the NGO's as well as the oil, gas and mining industry in remote areas is versatility. A significant gain in time and flexibility, the increase of transportation safety and productivity level can be obtained thanks to the use of aircraft presenting the prerequisites to be engaged in this very demanding market niche which is growing rapidly in Africa and in different parts of the world.

Aviation plays a key role in supporting mining around the world, and not just in areas lacking roads and railways. There are many missions executed by aircraft, both fixed wing and rotary wing in support of the mining industry. These include aerial surveying, aerial observation, the transport of staff to and from operations in remote or distant locations, the transport of key equipment to the mines and even the transportation of precious metals and stones from the mines where they have been extracted to secure locations in major centers.

Around the world, although it is not uncommon for mining companies to own one or more aircraft and operate the latter on a private basis, it is more usual for them to contract out their aviation support requirements to air operators, either through long-term or short-term charters or wet leasing (leasing aircraft plus crews, maintenance and insurance).

Many airfields available in Africa show restricted paved airstrip operational conditions due to lack of maintenance, or do not even have asphalt pavement. Grassy, dirt, laterite or gravel airstrips are very common on farms, small villages, or mining concessions that could previously only be reached by four wheel drive vehicles that travel long and dangerous isolated roads. Today the use of utility or executive aviation provides a safer, more reliable, faster, and more comfortable trip. Remote unpaved airstrips and their owners (government or private) face a multitude of unique issues due to the characteristics of the gravel or laterite material used, climate and seasonal impacts, geographic location, available resources and equipment and performance requirements.

In Africa, it is usual for mining projects to have their own landing strips. In the early prospection stages, these are usually unpaved, although seal-coated airstrips are getting more and more common at well-established operational mines. Most of the « Non-complex » turboprop aircraft with a seating capacity up to 19 passengers can be used all year round on unpaved airstrips as their performance usually does allow operations on wet unpaved airstrips during the rainy season. As the sites develop, the demand for transportation grows hence the requirements for aircraft with a larger capacity – but much more critical to operate – become a priority. An upgraded type of airstrip is a prerequisite for an all year round safe and optimal use of complex types of aircraft.

As far as the aircraft operators are concerned, one of the particularly challenging issues is the risk of damage to an aircraft resulting from bad airstrip conditions and/or Foreign Object Debris (FOD). Loose FOD can damage tires; strike the fuselage, propellers or other components; or be ingested into the engines. Due to the high risk of damage, most aircraft manufactures do not provide warranties for aircrafts operating on unpaved gravel airstrips, leaving the burden on the operators and airstrip owners.

3. Regulatory framework and aerodrome certification requirements

Public and private aerodrome certification is a process of ensuring that an aerodrome complies with the applicable safety rules, regulations, and specifications.

All member states of the Chicago Convention on International Civil Aviation (Chicago Convention) have obligations to comply with international specifications with regard to aerodrome certification requirements. ICAO Annex 14 Aerodrome Certification establishes criteria and procedures for the certifications of aerodromes.

ICAO Annex 14, Volume 1 contains all technical specifications and requirements associated with:

- Aerodrome Certification Requirements
- Design of Aerodrome Facilities
- Aerodrome Operational Services
- Aerodrome Operational Safety Issues

ICAO Annex 14, Volume 1, Chapter 1, Section 1.4 on Certification of Aerodromes stipulates the requirements. It also emphasizes the obligations and responsibilities of the Civil Aviation Regulating Authorities (regulator) and the airfield owner or operator

The Aerodrome certificate of compliance, whether public or private, is issued by the regulator, being the ANAC-BF (Agence Nationale de l'Aviation Civile – Burkina Faso) in the present case study.

☞ **The aerodrome certificate may be refused, or an existing certificate suspended for any of the following reasons:**

- Any non-compliance with the the regulator and/or Country of registration of aircraft regulations and safety requirements,
- Inadequate/unsafe operating procedures,
- Not following approved safety procedures and other risk mitigation action in case of exemptions granted,
- Safety Management System not functional, inactive, and ineffective, and
- Any significant safety concern as assessed by the regulator.

3.1 ICAO Aerodrome Reference Codes

3.1.1 Definition

The ICAO Aerodrome Reference Code is a two part categorisation of aircraft types which simplifies the process of establishing whether a particular aircraft is able to use a particular aerodrome. It is included in ICAO Annex 14 and is based on two elements Many airfields available in Africa show restricted paved airstrip operational conditions due to lack of maintenance, or do not even have asphalt pavement. Grassy, dirt, laterite or gravel airstrips are very common on farms, small villages, or mining concessions that could previously only be reached by four wheel drive vehicles that travel long and dangerous isolated roads. Today the use of utility or executive aviation provides a safer, more reliable, faster, and more comfortable trip. Remote unpaved airstrips and their owners (government or private) face a multitude of unique issues due to the characteristics of the gravel or laterite material used, climate and seasonal impacts, geographic location, available resources and equipment and performance requirements.
:

- the first element is **a numeric code** based on the Reference Field Length for which there are four categories and,
- the second element a: **is a letter code** based on a combination of aircraft wingspan and outer main gear wheel span.

3.1.2 Description

Element 1 of the Code is as follows:

Code Number	Airplane Reference Field Length	Typical Airplanes
1	< 800 m	DHC6 Twin Otter, Piper PA31 Navajo
2	800 m but < 1'200 m	ATR42-500, Bombardier Dash8-300
3	1'200 m but < 1'800 m	Saab 340, Bombardier Regional Jet CRJ-200
4	> 1'800 m	Boeing 737, Airbus A320

- **Field length** means the balanced field length (which is when the take-off distance required is equal to the accelerate-stop distance required) if applicable, or take-off distance in other cases.

- **Aeroplane reference field length** is defined as "the minimum field length required for take-off at maximum certificated take-off mass,
  (i) at sea level, in International Standard Atmosphere (ISA) conditions ,
  (ii) in still air,
  (iii) with zero airstrip slope as documented in the Aircraft Flight Manual (AFM) or equivalent document.
- **Field Width**. refer to § 3.1.3 below

Element 2 of the Code is derived from the most restrictive of either the aircraft wingspan or the aircraft outer main gear wheel span. The categories are as follows:

Code Letter	Airplane Wingspan	Typical Airplanes
A	< 15 m	Piper PA31 Navajo, Cessna 404 Titan
B	15 m but < 24 m	Bombardier Regional Jet CRJ-200
C	24 m but < 36m	ATR42-500, Boeing 737-700, Airbus A320
D	36 m but < 52m	Boeing 767-300
E	52 m but < 65m	Boeing 777/787, A330
F	65 m but < 80m	Boeing 747, Airbus A380

Note: Element 2 is often used on its own since it has direct relevance to detailed airport design. It also has a parallel but differently defined code use by the United States Federal Aviation Administration (FAA), the Airplane Design Group (ADG)

3.1.3 Airstrip Width

The primary parameter for determining the width is the Outer Main Gear Wheel Span (OMGWS) of the aircraft the airstrip is intended to serve. The width of an airstrip should be no less than the appropriate dimensions specified in the table below

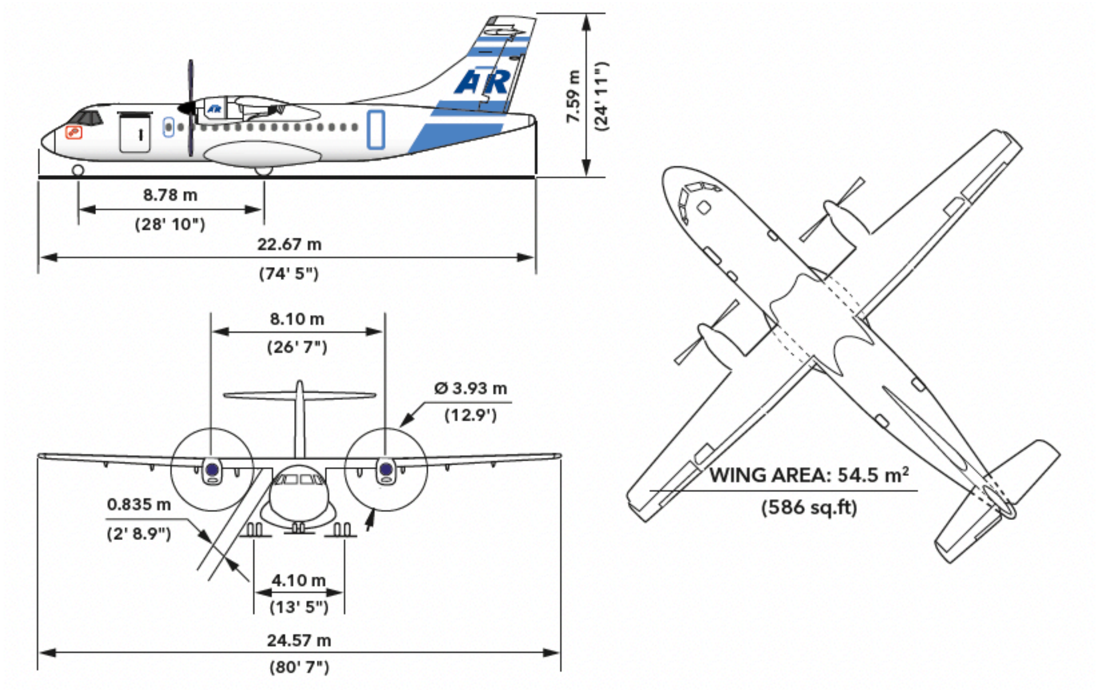
The airstrip widths shown below are the minimum widths considered necessary to ensure safety of operations. The factors affecting the minimum width of an airstrip are:

- Deviation of an aircraft from the centerline at touchdown,
- Crosswind condition,
- Airstrip surface contamination, (e.g., rain, snow, slush, or ice)
- Rubber deposits,
- Crab landing approaches used under crosswind conditions,
- Approach speeds used,
- Visibility,
- Human factors.

	Outer Main Gear Wheel Span (OMGWS)			
Code Number	Up to but not including 4,5 m	4,5 m up to but not including 6 m	6 m up to but not including 9 m	9 m but not including 15 m
1	18 m	18 m	23 m	---
2	23 m	23 m	30 m	---
3	30 m	30 m	30 m	45 m
4	---	---	45 m	45 m

3.1.4 Aircraft Characteristics

ATR42-500 General Dimensions



A list of aircraft operating in West Africa, chosen to provide examples of aerodrome reference code numbers and letter combinations is shown below. The table also provides data on the airplane reference field length (ARFL), wingspan and OMGWS used in determining the aerodrome reference code. The aircraft data is provided for planning purposes is indicative only. Exact values of a particular aircraft's performance characteristics should be obtained from information published by the aircraft manufacturer.

Aircraft Type	REF CODE	ARFL (m)	Wingspan (m)	OMGWS (m)	Length (m)	MTOW (kg)	Complex Aircraft
Cessna 172	1A	272	10,9	2,7	8,2	1'066	NO
Cessna 404	1A	721	14,1	4,3	12,1	3'810	NO
Piper PA31 Navajo	1A	639	12,4	4,3	9,9	2'950	NO
Cessna 208A Caravan	1B	296	15,9	3,7	11,5	3'310	NO
DHC6 Twin Otter	1B	695	19,8	4,1	15,8	5'670	NO
Beech 1900	2B	811	16.6	5,8	17,6	7'530	YES
Pilatus PC-12	2B	810	16,3	4,5	14,4	4'740	NO
Pilatus PC-24	2B	893	17,0	3,3	16,8	8'300	YES
ATR42-500	2C	1'165	24,6	4,1	22,7	18'600	YES
Dash8-300	2C	1'122	27,4	8,5	25,7	18'642	YES

3.2 Rescue and Fire Fighting Services

Rescue and Fire Fighting Services (RFFS) is also commonly referred to as Aircraft Rescue and Fire Fighting (ARFF) and occasionally as Crash Fire Rescue (CFR). In all cases, these terms refer to the rescue and fire fighting services provided at an aerodrome which are specifically dedicated to the support of safety in aircraft operation.

3.2.1 Background

ICAO defines the requirements for aerodrome RFFS in Annex 14, Volume 1 - Aerodrome Design and Operations. In accordance with this Annex, it is a requirement for Member States to provide rescue and fire-fighting services and equipment at airports under their jurisdiction. ICAO Document 9137-AN/898, Airport Services Manual, Part 1, Rescue and Fire Fighting provides guidance in the implementation of the Annex 14 requirements thereby helping to ensure uniform application amongst the Member States.

The Civil Aviation Authority of each State in turn publishes the corresponding regulations and guidance for their operators whether public or private.

3.2.2 Capacity

Although there is some disparity among the Member States in the designation of the RFFS capacity of a given aerodrome, the basic premise for determining the normally-declared RFFS requirement is the size of the largest aircraft that it is intended to accept.

In most cases, the size determination is based on both the length of the aircraft and the maximum fuselage diameter. As an example, the following chart has been extracted from the Canadian Aviation Regulations (CARS).

Aircraft Category for Fire Fighting	Aircraft Overall Length	Aircraft Maximum Fuselage Width
1	< 9 m	2 m
2	9 m ≤ length < 12 m	2 m
3	12 m ≤ length < 18 m	3 m
4	**18 m ≤ length < 24 m**	**4 m**
5	24 m ≤ length < 28 m	4 m
6	28 m ≤ length < 39 m	5 m
7	39 m ≤ length < 49 m	5 m
8	49 m ≤ length < 61 m	7 m
9	61 m ≤ length < 76 m	7 m
10	≥ 76 m	8 m

To meet the requirements of the Aircraft Category for Fire Fighting, it is necessary for the aerodrome to have a declared minimum fire fighting capacity measured on the basis of the number of available vehicles and their foam production capability. In this respect, the declared Category is that actually available at the time of an aircraft approach, which may temporarily be lower than the Category normally available and so promulgated in official reference publications.

Critical Category for Fire Fighting	Quantity of Water	Quantity of Complementary Extinguishing Agents	Minimum Number of Aircraft Fire-fighting Vehicles	Total Discharge Capacity
1	230 l	45 kg	1	230 l/min
2	670 l	90 kg	1	550 l/min
3	1200 l	135 kg	1	900 l/min
4	**2400 l**	**135 kg**	**1**	**1800 l/min**
5	5400 l	180 kg	1	3000 l/min
6	7900 l	225 kg	2	4000 l/min
7	12100 l	225 kg	2	5300 l/min
8	18200 l	450 kg	3	7200 l/min
9	24300 l	450 kg	3	9000 l/min
10	32300 l	450 kg	3	11200 l/min

Both the above tables are provided for illustrative purposes only. The ones provided by some regulating agencies of Member States may be slightly different.

3.2.3 Downgraded Fire Fighting / Rescue Equipment

EASA Operations Manual A (OM A), Chapter 8 Operating Procedures, § 8.1.2 Criteria for determining the usability of aerodromes
provides for the following provisions in the event of lack of fire-fighting equipment

QUOTE

8.1.2.2.1 Downgraded Fire Fighting / Rescue Equipment

The firefighting and rescue services may have different categories of cover for given operating hours or may be notified by NOTAM to be temporarily at a lower category than published. If the firefighting and rescue service category at destination is lower than that required for the specific aircraft type the Nominated Postholder (NP) Flight Operations will request that, if possible, the firefighting and rescue service is upgraded to the required category for the period of operation. Should an upgrade to the required category not be possible than operation may be sanctioned at a downgraded category provided the NP Flight Operations produces and sends a Risk Assessment for the destination to the aircraft Commander, considering the operation a lower category of Firefighting and Rescue service than normal.

☞ *If at the planned destination, the rescue and firefighting capacity is officially downgraded the following shall apply:*

- *No protection available:*
  - *The aerodrome must NOT be used*

UNQUOTE

Remark: The feasibility study issued the Burkinabe Civil Aviation Authorities on 19.03.2019, for the construction of Customer's airstrip on the premises his mining concession. Its Chapter 8 *"Protection du domaine aéroportuaire et sécurité" § 8.2 "sécurité incendie »* that **firefighting and rescue is placed under the responsibility of the Customer in line with the critical aircraft's requirements (Cessna C208B Caravan)**
"La société minière doit assurer la fourniture du service de lutte et de sauvetage contre l'incendie d'aéronef sur l'aérodrome en adéquation avec les caractéristiques de l'aéronef critique »

4 Complex Vs. Non-Complex Aircraft

4.1 Definition of complex aircraft

According to the scope of Regulation (EU) No 965/2012 and its subsequent amendments, the term « complex motor-powered aircraft » or **COMPLEX AIRCRAFT** refers to:

1.an aeroplane :
- with a maximum certificated take-off mass exceeding 5,700 kg; or
- certificated for a maximum passenger seating configuration of more than nineteen (19) ; or
- certificated for operation with a minimum crew of at least two pilots; or
- equipped with (a) turbojet engine(s) or more than one turboprop engine; or

2.a helicopter certificated:
- for a maximum take-off mass exceeding 3,175 kg; or
- for a maximum passenger seating configuration of more than nine; or
- for operation with a minimum crew of at least two pilots; or

3.a tilt rotor aircraft.

☞ An aircraft not meeting the above criteria is an 'other-than-complex motor-powered aircraft' or NON-COMPLEX aircraft.

5 Complex Aircraft Operational Environment :

Same complex aircraft operated in atmospheric, and operations friendly environments are in completely different situation and to run safe and sustainable air transportation services airline must perfectly know how to adapt. Complex aircraft operated in "hot & high" environment with unpaved and short airstrips without non-precisely covered areas for navigation are incomparable with same aircraft type flying the routes in middle Europe on medium sized airports and full navigation coverage.

Typical 40-50 seat turboprop aircraft on European scheduled passenger operations constraints versus African dedicated air transport services Operations on mixed airstrips and airstrips can be summarized as follows:

	European scheduled passenger operations	African dedicated passenger and cargo services
Base Maintenance Facilities	Available at home base	Line and light maintenance only available on site
Environment	Friendly	Non-Friendly
Hot & High	NO	YES (most of the time)
Airframe constraints	Low	High
Operations	Passenger (very little cargo)	Passenger and cargo
Load Factor	65 – 70 %	95 %
Landing Gears	Paved airstrips	Mixed airstrips
Propeller reverse	Long Airstrips	Short Airstrips

ATR72-500 on the ground in Khartoum, Sudan after a heavy rainstorm

6 Runway/ Airstrip pavement surface types

6.1 Definitions

- **Unpaved Surface:** A surface, intended for aircraft operations, composed of unbound or natural materials. Unpaved surfaces may include gravel, coral, sand, clay, hard packed soil mixtures, grass, turf or sod. (*Note: Unpaved surfaces are also referred to within the aviation industry as « Unimproved Airstrips »)*

- **Unpaved Airstrip:** A airstrip pavement constructed with an unpaved surface.

- **Unprepared Surface:** Any naturally occurring surface used as a airstrip that has not been altered by man

6.2 The various surface types

There are various pavement surface types used to describe airstrip pavement. The following descriptions are provided in the Boeing airport compatibility manual:

6.2.1 Macadam: (sometimes called tarmacadam, or tarmac) - Uniformly sized stones rolled or compacted in-place, and usually sealed by an asphalt treatment that penetrates into the uppermost portion of the surface or coated with tar or bitumen. Usually, such surfaces are thin by typical airport standards, on the order of 2 to 5 centimeters thick.

6.2.2 Gravel airstrip - An airstrip, typically constructed of a mixture of compacted soils and stones or laterite, the latter also being referred to as "**laterite airstrip**", with a surface that is not bound by any additives (neither asphaltic nor cementitious). **Such airstrips are classified as "unpaved" and are sometimes referred to as "unimproved"**. A grass airstrip usually does not qualify as a gravel airstrip.

6.2.3 Flexible Pavement – A runway, taxiway, or ramp that is surfaced with a mixture of asphaltic materials (asphalt and aggregate) of from 8 to 13 centimeters or more in thickness. **This type of construction qualifies a runway to be referred to as "hard surfaced" or "paved" and** is also known as an "asphalt" pavement.

6.2.4 Rigid Pavement - A runway, taxiway, or ramp that is surfaced with a mixture of concrete materials (Portland cement, sand, coarse aggregate, and water) of from 15 to 50 centimeters or more in thickness. Typical narrow body runways usually have 28 to 33 centimeters of concrete thickness, and runways that serve wide body aircraft usually have 43 to 50 centimeters of concrete thickness. **This type of construction qualifies a runway to be referred to as "hard surfaced" or "paved" and is also known as a "concrete" pavement.**

6.2.5 Seal Coat - This type of runway is usually an unpaved (gravel or laterite) airstrip, the surface of which has been treated with a sealant (usually asphaltic or resinous) to create a well-textured, waterproof surface that typically has a total thickness of less than one to two centimeters. Such surfaces generally stand up well to high tire pressures or high wheel loads. If the surface is unbroken, the airstrip is considered paved or hard surfaced. See example of certification of a sealcoat application on an unpaved airstrip in Chapter 11 hereto

6.2.6 Slurry Seal - A mixture of well-graded fine aggregate, mineral filler, emulsified asphalt and water, applied to a runway or an apron as a surface treatment. **Slurry seals are generally only applied to previously paved surfaces**.

7 Operations on unpaved airstrips

ICAO Annex 14 (Aerodromes) requires each member country to report information on pavement strength for all airports with commercial operations in the format of publishing information that it establishes in its aeronautical regulations (AIP)

7.1 Description

Unpaved airstrip surfaces can be subject to significant variations in their strength and surface characteristics because of climatic effects and the effects of aircraft operations.

Unpaved airstrips can achieve their design strength and surface characteristics when maintained properly and not subject to excessive moisture. Gravel and laterite surfaces deteriorate with time and under repeated traffic loadings. The most common defects occurring with unpaved surfaces are ruts, depressions, potholes, soft spots and loss of aggregates. Periodic grading, compaction and addition of new material are required to maintain the integrity of the gravel surface and to ensure the safe operation of aircraft.

Unpaved airstrip surfaces are typically non-homogeneous in composition and may contain various types of soils. Soil classification is used to predict the probable behaviour of soils under the influence of frost and moisture.

- **The California bearing ratio** (CBR) provides a measure of the ability of an unpaved surface to resist shearing under aircraft loads. CBR is the ratio of the load bearing capability of a given sample of soil compared to that of crushed limestone. The CBR of a given soil test is expressed as a percentage ranging from 0% to 100% or a whole number ranging from 0 to 100.

- CBR should be considered an index of airstrip surface strength as opposed to an absolute or true value of shear strength, because of the dependence of the CBR value on the measuring device used

7.1.1 Definition of ACN-PCN

Aircraft classification number (ACN): defined as a number expressing the relative effect of an airplane of a given weight on a pavement structure for a specified standard subgrade strength based on a specified standard. Use of the standardised reporting method for pavement strength applies only to pavement intended for complex aircraft operations

- **Aircraft classification number (ACN**): defined as a number expressing the relative effect of an airplane of a given weight on a pavement structure for a specified standard subgrade strength based on a specified standard.

- **Pavement classification number (PCN**): is defined as a number expressing the bearing strength of a pavement for unrestricted operations.

The ACN-PCN system is a method used solely for reporting the relative strength of pavement, based upon which airport operators are able to determine whether operation of their airplanes is acceptable. It is not intended as a pavement design method or a pavement assessment procedure, nor does it restrict the methodology used to design and assess a pavement structure.

7.2 Weather and wear effects on unpaved airstrips

Conditions of excessive moisture, such as those found during heavy precipitation and poor drainage can result in a significant degradation in airstrip surface strength.

The degradation in surface strength may be enough to limit or completely restrict operational use.

The following factors can adversely affect unpaved airstrips:

- Loss of material resulting in bare spots and sub-grade material appearing on the surface;
- Accumulation of loose, non-cohesive aggregates on the surface because of material segregation;
- Formation of ruts in wheel paths;
- Persistence of damp or wet areas because of poor surface drainage;
- Soft areas during wet conditions;
- Airstrip roughness or longitudinal unevenness (waviness); and
- Vegetation growth.

7.3 Reactionary effects of rainy season on Customer’s unpaved airstrip operations

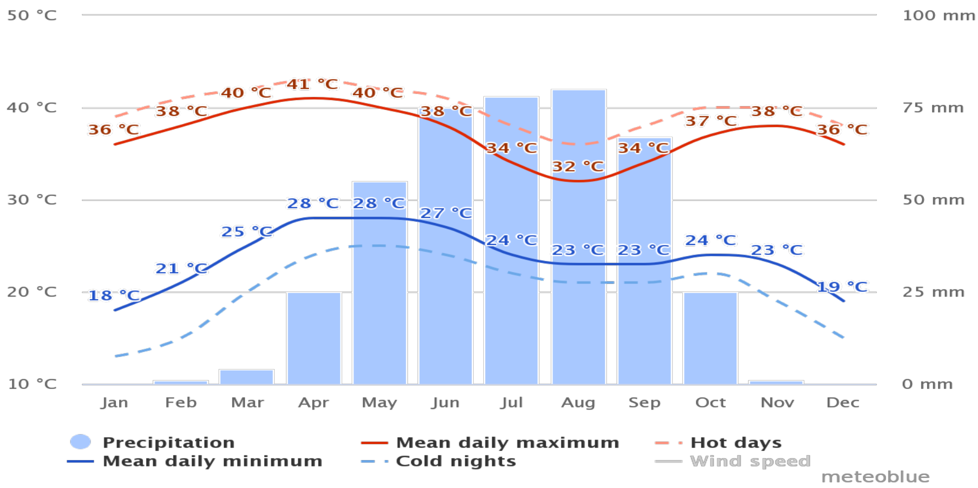
As set forth in § 7.6.1 below, a complex aircraft such as the ATR42 is only certified on DRY airstrips.

While the DHC6-300 “Twin Otter can operate almost without restrictions under WET conditions, major operational issues are to be expected during the rainy season as part of a complex aircraft operation at Customer’s airstrip in its current pavement state.

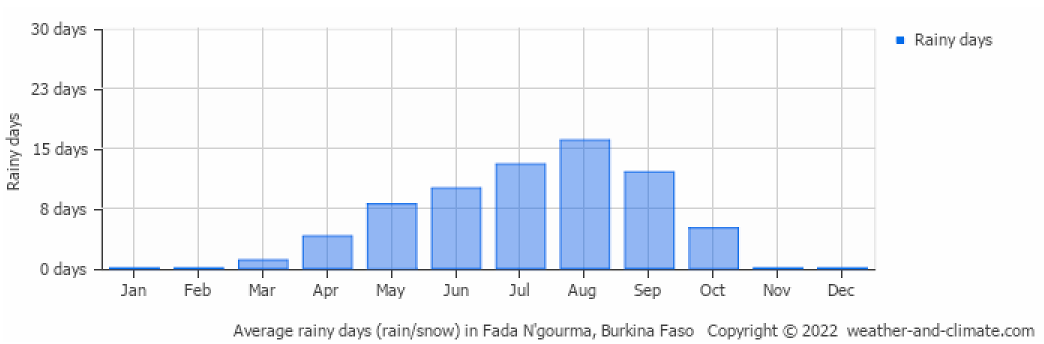
Reactionary effects over several days on the entire flight program can be expected as follows:

- Holding over airfield waiting for an improvement of conditions.
- Reduced payloads due to higher reserve fuel requirements.
- Flight delays.
- Flight cancellations.
- Diversions to alternate airport.
- Return to departure airport.

Annual temperatures and precipitations measured at Fada N'Gourma (62 nautical miles from the Customer's airstrip)



Annual average rainy days at Fada N'Gourma (62 nautical miles from the Customer's airstrip)



- Most rainy days are in August.
- The area where Customer's airstrip is located has dry periods in January, February, March, November, and December.
- On average, August is the most rainy with 16 days of rain/snow.
- On average, November is the driest month with 0 rainy days.
- The average annual amount of rainy days is 70.

The DHC-6 Twin Otter on take-off at Barra, Scotland: the only airfield in the world where scheduled flights use a tidal beach as the runway

7.4 Effects of unpaved airstrips on aircraft performance

- Increased takeoff distance due to the increased rolling resistance (caused by the deflection of the surface under the load of the aircraft).
- Increased stopping distance due to reduced braking performance.
- Increased accelerated stop distances (in case of rejected take off) due to the factors mentioned above.
- Degraded handling on the ground (during take-off and landing roll as well as ground manoeurving). The use of nosewheel steering may be necessary for improved handling, or in some cases prohibited if incompatible with unpaved surfaces.
- Procedures and equipment necessary to protect an aircraft may also have an adverse effect on takeoff and landing performance. The procedures usually limit pilot intervention and most protection equipment (e.g. shields, deflectors, etc.) impacts aircraft aerodynamics and weight.

7.5 Aircraft Protection

Protection of aircraft components is necessary so that operators can safely use aircraft on unpaved surfaces. Operators typically achieve this through special procedures and equipment, e.g.:

- Gradual application of thrust or power to minimize the ingestion of materials by engines or damage to propellers;
- Limited or prohibited use of reverse thrust ;
- Configuration of bleed air systems to minimize dust ingestion;
- Reducing tire pressure without changing the aeroplane weight, which results in the redistribution of the wheel load over a wider area thus reducing airstrip surface deflection and tire rolling resistance. This may be limited, however, by the tire design and the necessity to avoid excessive deflection of the tire under load;
- Reduction of aircraft weights if operating under reduced tire pressures;
- Aircraft modification with oversize, floatation or balloon type low pressure tires for operations on soft unpaved surfaces;
- Installation of protective systems (e.g. shields, deflectors, and filters, abrasion-resistant finishes, etc.). These protect the aircraft from hazards caused by the impingement and ingestion of stones, dust and debris.

7.6 Aircraft Certification

Any modifications having a significant or appreciable effect on the aeroplane require an Aircraft Certification approval, in the form of a Supplemental Type Certificate (STC) or an equivalent approval document.

A supplement to the Airplane Flight Manual (AFM), to provide the appropriate limitations, procedures and performance information (or data) for unpaved surface operations is normally required as part of a certification approval. The AFM supplement should also provide a surface definition to identify the characteristics of unpaved airstrip surfaces from which the aircraft has been certified to operate.

Any alterations of tire pressure, or types of tires used should be considered to be major modifications to an aircraft. These changes should undergo an aircraft type certification approval process. Systems such as anti-skid and nose-wheel steering should be specifically evaluated for unpaved airstrip operations to determine and identify any handling differences.

Many small aeroplanes and older large aeroplanes do not have aircraft certification approvals or AFM information for unpaved airstrip operations. Some manufacturers have provided unapproved information, often called manufacturer's data as guidance for operations on specific unpaved surfaces.

Some Civil Aviation Authorities found that many air operators do establish specific operational procedures for unpaved airstrip operations to protect their aeroplanes from any adverse effects, but they may not account for the degraded aeroplane performance.

See Example of aircraft unpaved runway certification process at Chapter 10 hereunder

7.6.1 ATR Special Operations procedures – DRY unpaved airstrips

DRY unpaved operations approval reflects the capability of the aircraft as evaluated by its manufacturer in terms of airworthiness, but it does not constitute approval for operations in case such operational approvals required by the national Civil Aviation Authorities to the Operators and/or the local Civil Aviation Authorities.

☞ An individual clearance for each unpaved airstrip must be obtained by the Operator from the national Civil Aviation Authority and/or the local Civil Aviation Authorities

☞ The ATR42-500's Aircraft Flight Manual (AFM) Supplement 8.2 "Limitations" defines the following conditions for operation of an ATR42-500 on dry unpaved airstrips:

QUOTE

8.2.1 Airstrip Condition

- ***DRY airstrips only, for laterite, soil or grass surface materials***
- ***Gravel airstrips: provided they have a uniform covering of surface material that is graded smooth and kept free from ruts and standing water.***
- *The surface bearing material must be not less than 6 in in depth*
- *The airstrip surface is well compacted, with few loose stones the largest dimension of which does not exceed 50 mm (2 in)*
- *There are no large vegetation tufts*
- *The airstrip is clear of undulations and ruts*
- *The CBR is equal to or greater than 4.*
- *However with CBR between 4 and 8 superficial damages may be caused to the airstrip*
- *The stopway, if any, has similar characteristics*
- *The airstrip is inspected with a frequency connected to local conditions, to be sure that above conditions are satisfied.*

8.2.2 Landing Gear and structural limitations

- *Landing on unpaved airstrip must be recorded. Refer to time limits at the latest update*

8.4.1.3 Landing

For Flight Preparation Computation

- For dry unpaved airstrips:

o On soil, laterite or gravel airstrips, to compute Actual Landing distance:
- *Compute the Actual Landing Distance on dry hard-surfaced airstrip corrected of weight and altitude effect only*
- *Then add 60 m (197 ft) to this value,*
- *Then, apply other effect corrections.*

o On grass airstrips, to compute Actual Landing distance:
- *Compute the Actual Landing Distance on dry hard-surfaced airstrip corrected of weight and altitude effect only.*
- *Then add 120 m (394 ft) to this value,*
- *Then, apply other effect corrections.*

To determine the required airstrip length, apply national operational regulations

UNQUOTE

7.6.2 ATR Special Operations procedures – WET and contaminated gravel airstrips

As described in § 7.5.1 above ATR allows operations on gravel unpaved airstrips but not on all airstrip conditions and not for the entire ATR fleet. It depends on the ATR aircraft type, and modification embodied

ATR proposes an extension to WET and CONTAMINATED GRAVEL UNPAVED airstrips to all ATR fleet under the following conditions:

- Embodiment of additional protections as described under § 7.4 hereto (MOD 05038 for the ATR42-500)
- Airstrip surface type is GRAVEL (uniform covering of surface material)
- Airstrip surface is either wet or uniformly covered by either compacted snow or ice

The benefits are:

- No penalty factor applied on take-off and landing computation for wet and contaminated gravel unpaved airstrips, The performance impact of a contaminated airstrip is the same, whether the airstrip is paved or unpaved

Remark: Operations on wet and/or contaminated unpaved gravel airstrips are already allowed on some other competitor aircraft types

7.6.3 ATR Special Operations procedures – Narrow runways

This modification enables operational capability on narrow runways and airstrips down to a minimum of 14 meters width instead of 30 meters. It consists in updating the AFM and the Flight Crew operating Manual (FCOM). Embodiment of this modification induces a correction of crosswind limit on take-off and landing.

Narrow runways operation reflects the capability of the aircraft as evaluated in terms of airworthiness but does not constitute approval of operations. Narrow runway capability is subject to approval by the Civil Aviation Authority of the Operator and local Civil Aviation Authorities on a case-by-case basis is subject

8 Aircraft damage from operations on untreated unpaved airstrips

The direct cost of FOD-and untreated surfaces related damage are a constant challenge to complex aircraft operators ranging from as low as tens of thousands of dollars to easily exceed one million dollars, not to mention the indirect costs associated with flight delays, aircraft changes, unscheduled maintenance, etc.

In a study released by SRI in 2018, it has been determined that indirect costs arising from a FOD or airstrip condition-related damage often equal 10-13x the direct costs. Indirect costs listed by the report include and are not limited to:

- Change of aircraft
- Close airstrip
- Corporate manslaughter/criminal liability
- Cost of corrective action
- Cost of hiring/training replacement
- Cost of rental or lease of replacement equipment
- Cost of the investigation
- Fines and citations
- Increased insurance premiums
- Increased operating costs on remaining equipment
- Insurance deductibles
- Legal fees resulting
- Liability claims in excess of insurance
- Loss of aircraft
- Loss of business and damage to reputation
- Loss of productivity of injured personnel
- Loss of spares or specialized equipment
- Lost time and overtime
- Replacement flights on other operators
- Scheduled and unscheduled maintenance

More importantly than the significant economic impact that FOD and untreated surfaces can have on an air operator's operation FOD and airstrip condition related incident pose serious safety concerns and can result in aircraft failure, leading to the possible injuries or casualties and total write-off of the aircraft.

This research studied airports with paved airstrips only, meaning not all items will be relevant to unpaved airstrips. However, government-owned and private unpaved airstrip operators should consider these numbers with concern, because unpaved airstrips by their nature create far more FOD and/or other damage to aircraft directly from airfield infrastructure, meaning unpaved airstrip operators are more likely to be held liable and less likely to be able to afford the hit of any occurrence listed above.

Besides impacting the aircraft's skin, systems, tires and propellers, untreated airstrip surfaces also may impact :

- steering,
- braking,
- takeoff and landing distances and performance.

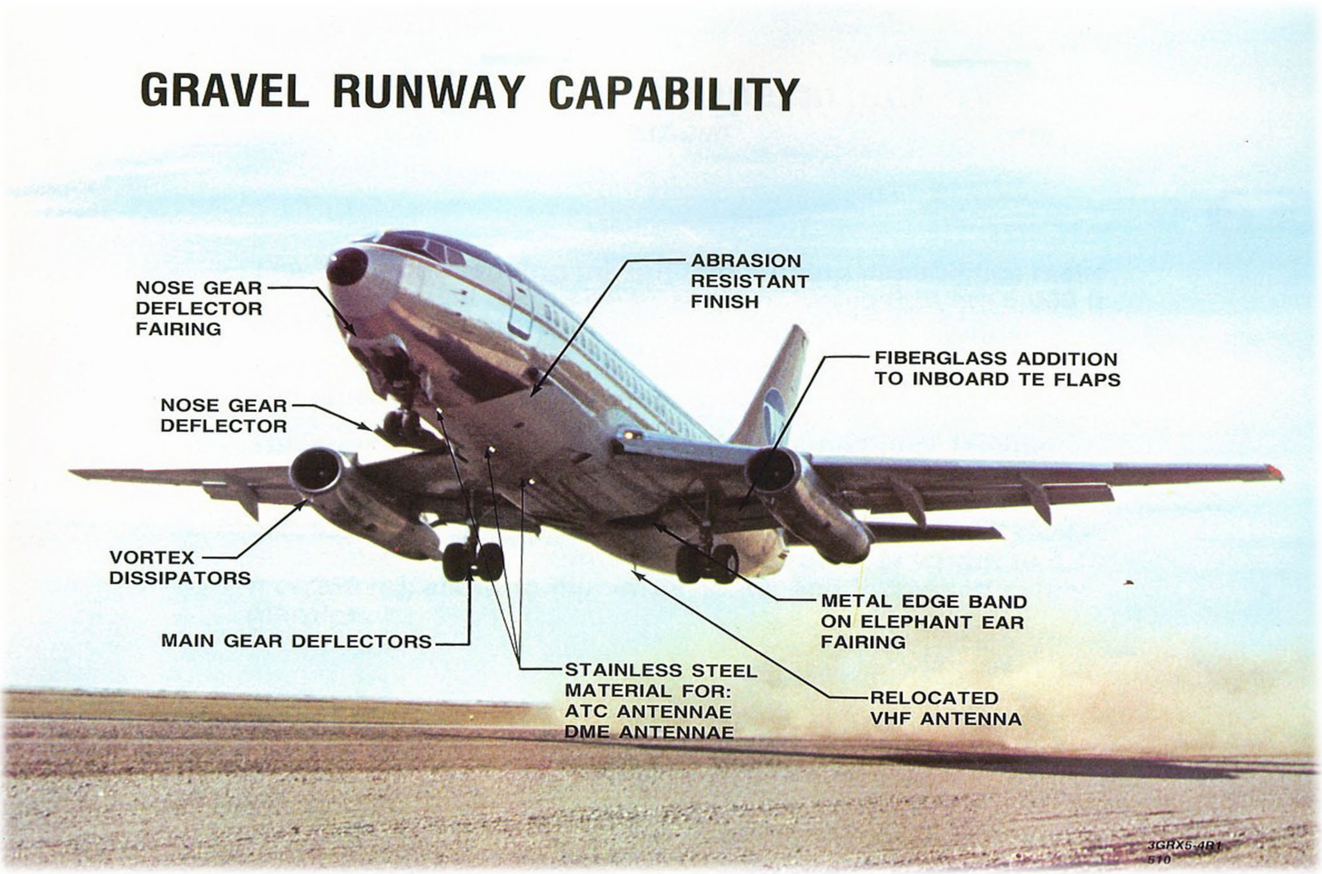
Potholes, rutting, wash boarding, loose gravel/FOD and water pooling/ponding all contribute to challenging conditions and, in some cases, risks that pilots must assess and be aware of while operating from untreated gravel or laterite airstrips.

8.1 Gravel kits no longer prevent aircraft damage from gravel airstrips

In the past, certain complex aircraft manufacturers such as Boeing provided their aircraft with optional gravel kits to ensure added durability and protection when operating on unpaved airstrips. Gravel kits are structural modifications to an aircraft to avoid/minimize FOD damage or ingestion while operating on unpaved surfaces, allowing larger aircraft, such as the Boeing 737-200, to land on unpaved surfaces. They helped to mitigate the impacts loose gravel and dust have on aircraft. These modifications generally included deflectors, vortex dissipators, shields and reinforcements—all designed to prevent damage to the engines, underside of the fuselage and the wings. Gravel kits have been vital to protecting aircraft, keeping pilots safe and avoiding costly repairs.

Boeing 737-200 nose landing gear gravel deflector.

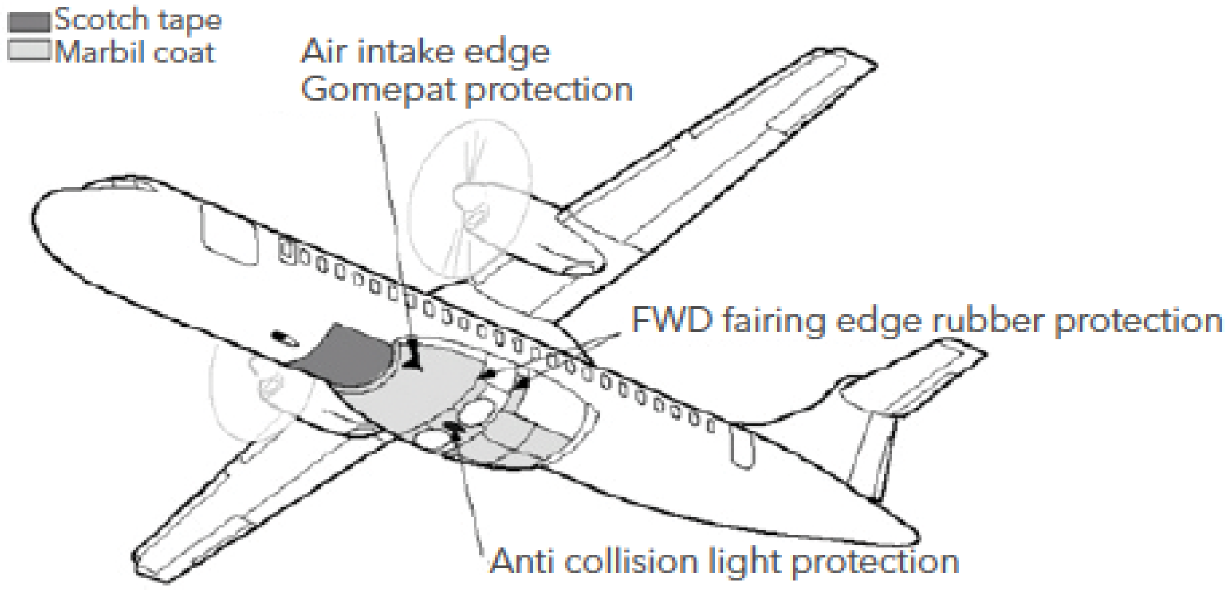
Boeing 737-200 engine anti FOD ingestion protection (tube which blows pressure regulated (55psi) engine bleed air down and aft from 3 nozzles at the tip to break up the vortices)



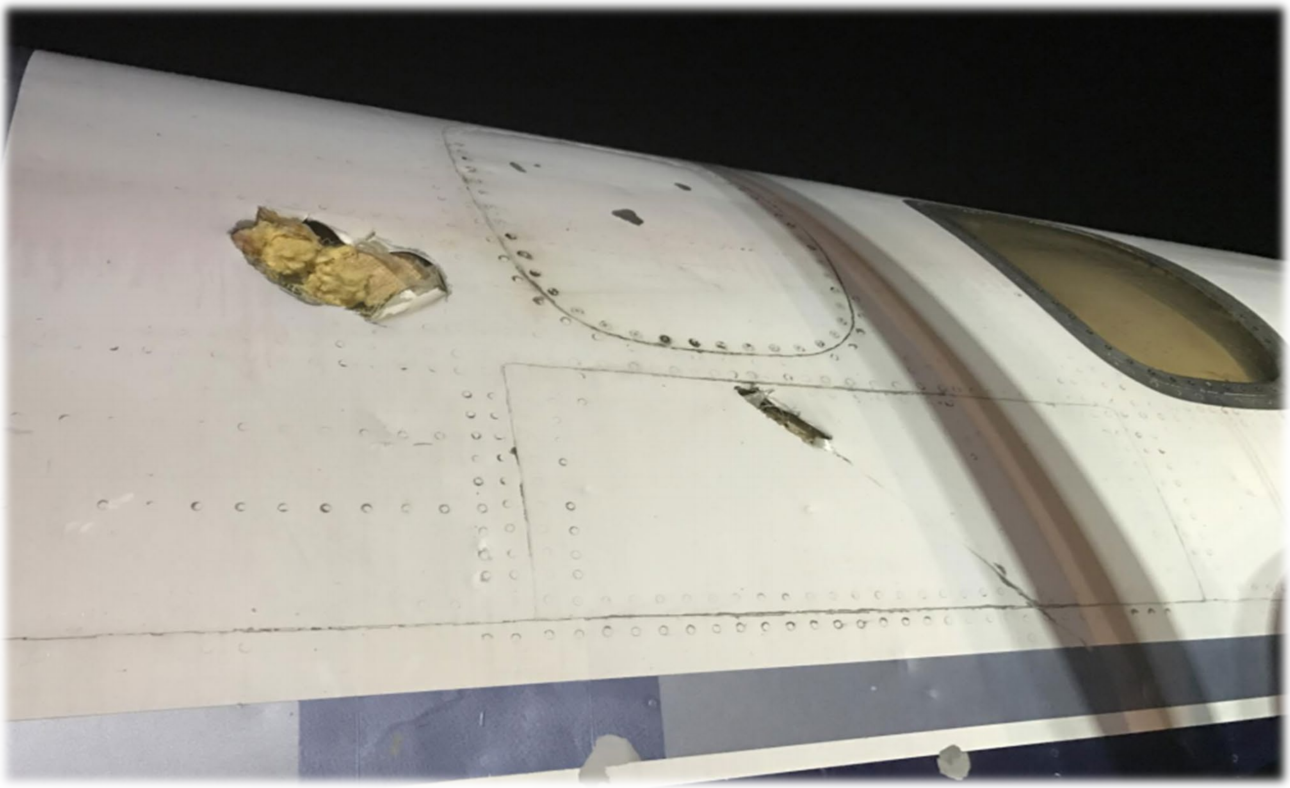
However, in recent decades, complex aircraft manufacturers have discontinued the installation of gravel kits on new aircraft and have almost entirely phased out older aircraft that were equipped with gravel kits. This is a major and costly problem for operators , by making newer aircraft more vulnerable to FOD. Most of the new aircraft are today purely and simply unable to operate on unpaved airstrips (Boeing 737 Classic and Next Generation, Airbus A220, A320 family etc.)

The only exception to the rule so far is the Pilatus PC-24 (PC-24), a recent complex light jet aircraft designed from the ground up for executive travel, MEDEVAC and transport of people and equipment with both dry and wet unpaved airstrip capabilities (see report on certification process under Chapter 11)

Newer commuter aircraft such as the ATR and Dash-8 families operating on unpaved airstrips without any protection are highly susceptible to costly damage from loose surface particles ranging in size from as small as 1 millimeter up to 3 centimeters and larger. Therefore, in order to reduce damage risk on gravel airstrip operations, ATR has developed metallic main landing gear and landing gear door protections. Optional Additional fuselage protections are installed as follows on the ATR42-500:



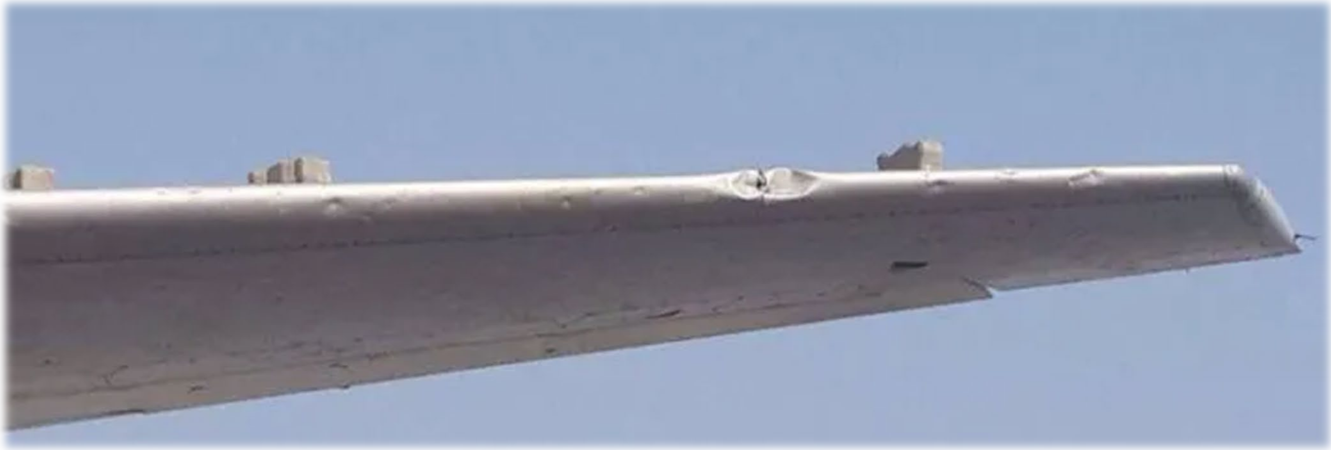
Examples of FOD-related propeller damage from gravel airstrips.



Example of FOD-related heavy aircraft skin damage

Loose surface material or a failure of surface strength can cause a plane's tires to literally sink into the airstrip, trapping it.





It appears that the hard surface was made from the interlocking concrete paving stones that are commonly used for patios and garden walkways….

Extensive dust in the air increases the risk of engine incidents

9. Aircraft maintenance costs and maintenance reserves

Whether operated in a friendly environment all year round on long, paved and well-maintained airstrips or under the most severe conditions prevailing in Africa no aircraft is tolerant of neglect.

No aircraft is safe in the absence of an effective inspection and maintenance programme. The processes that normally affect an aircraft are deterioration with age (e.g. fatigue, wear and corrosion) as well as chance failures (e.g. tyre burst, excess structural loads). Such deterioration processes are significantly accelerated when the aircraft is frequently operated on unpaved airstrips

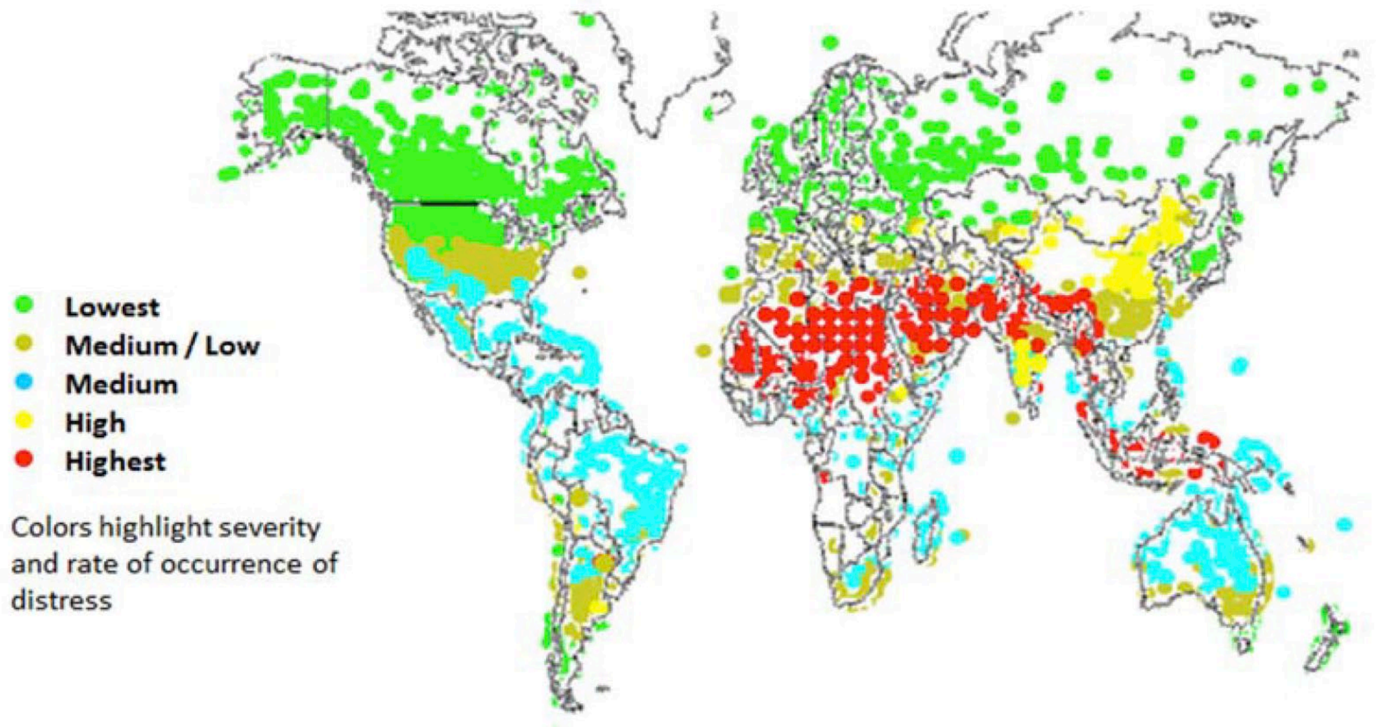
Maintenance will consist of a mixture of preventive and corrective work, including precautionary work to ensure that there have been no undetected chance failures. There will be *inspections* to monitor the progress of wear out processes, in addition to:

- Scheduled or preventive maintenance work is performed at regular intervals and includes a daily check, a pre-flight check, inspection at regular intervals, annual inspections and progressive inspections to anticipate and prevent failures.

- Unscheduled maintenance work – Repair maintenance and on-condition maintenance, occurs anytime a component has malfunctioned or is suspected of malfunctioning or a damage to the aircraft or one of components is visible or suspected. It can occur after a pilot or an engineer finds a problem during the preflight inspection, as a result of an in-flight malfunction or as a result of problems found during a scheduled inspection. Unscheduled maintenance could be anything from a worn tire, a low landing gear strut or an oil leak on an engine. At this point the aircraft would be grounded until the problems are repaired and the aircraft is deemed to be airworthy by the engineers.

Unscheduled maintenance work is likely to become a major concern should the aircraft be frequently operated on unpaved airstrips in bad condition.

The engine and airframe environmental distress chart below clearly demonstrates that African areas in desert, equatorial and tropical savannah climates present the highest severity and rate of occurrence of damage



Engine and airframe maintenance environmental distress chart

9.1 Maintenance costs

After fuel, aircraft maintenance is the second biggest cost to an operator. Furthermore, the lack of Maintenance, Repair and Overhaul Organizations (MRO) in Central Africa generates heavy positioning costs to take the aircraft to North or South Africa, Kenya, Ethiopia or overseas when heavy maintenance becomes due.

Scheduled maintenance costs will vary according to the class of aircraft, for example jets vs. turboprops vs. pistons vs. helicopters.

Scheduled maintenance costs will also vary according to aircraft type, i.e., a light jet vs. a medium vs. a long range.

Regardless of the class or type of aircraft, industry literature, surveys, records, annual flight hours and flight cycles, flight hours/cycle ratio,, dispatch reliability and pilot reports are permanently analyzed to find out what the scheduled maintenance cost drivers are or a specific type of aircraft operated on specific routes.

Scheduled maintenance costs are :

- Predictable because they are normally tied to a scheduled event, and
- Easier to estimate because they are larger in amount, therefore, they receive more attention, which causes better available information and with some research will generally yield an average cost.

Unscheduled maintenance means trouble for the operator, so it must be handled as quickly as possible because:

- It disrupts the scheduling of the aircraft and may require a spare aircraft to be assigned against its regular program if the problem persists.

- It might be required somewhere that the airline doesn't have a full station support presence (e.g. at the Customer's private airfield located on the mining concession), meaning that the engineers must go to it or the aircraft must be brought to them -- both options can be quite expensive in terms of dollars and delay.

If some component that's required by the Minimum Equipment List (MEL) fails , the aircraft doesn't fly without special permission, An empty of "ferry" flight might be allowed under some conditions, but each must be individually approved by the Operator and in some cases by the Civil Aviation Authorities.

9.2 Maintenance reserves

Maintenance reserves generate a significant part of operator costs.

The main objective of collecting of maintenance reserves is to be prepared for major maintenance event or for repair of main assemblies, thus guarantee enough savings and avoid sudden investments putting the operator or the operation in danger. Underestimation of maintenance reserve rates will create major financial issues within the operator and there are cases of operator bankruptcy due to this reason.

On the other hand, overestimation will make the operations of the aircraft so expensive, that Customer will simply disagree and choose another operator presenting a better offer.Optimizing and review of set up of reserve rates should be done periodically and if possible and necessary, to adjust them according to real aircraft status.

☞ **The biggest influence on reserve rates is generated by the type of missions and environment where the aircraft is operated.**

Many operators are often relying on published maintenance reserves rate per event by the aircraft manufacturer. Unfortunately, it's not always reflecting reality, in particular when the aircraft is operated under unusually rough conditions.

Besides the ype of operations and environment the real value of the event must be understood, as well as what exactly is included in calculated costs.

Unscheduled maintenance tasks may significantly change expected costs, and this must be understood and managed from beginning of building up the reserves.

Typical events covered by maintenance reserves (depends on aircraft type) are following:

- Aircraft Base maintenance Inspections (C-Checks, D-Checks, Annual Checks, Mid Life Checks etc.)
- Landing Gear Overhaul Costs (important to include subassemblies the landing gear)
- Engine Performance Restoration
- Engine Life Limited Parts Replacement (blades, compressor, seals and disks)
- Auxiliary Power Unit Restoration
- Propeller Blades Overhaul

9.3 Airworthiness limitations for ATR42-500 operations on unpaved airstrips (MOD 5038)

ATR has issued a supplement to the Airworthiness Limitations Section of the Time Limits documents to be applied by operators which use the capability of their aircraft to operate on unpaved airstrips as certified per Modification 5038 on the ATR42-500. The supplement indicates the flight count factors which must be applied on the affected lifetime limited items.

The appropriate flight count factor must be applied to each landing performed on an unpaved airstrips in order to comply with the mandatory limitations.

The life limit only affects main landing gear components when operated on unpaved airstrips A flight count factor must be applied to each landing for a total of 27 listed parts.

Flight count factor for landing on unpaved airstrip varies between 1.1 and 3.56, depending on the listed part.

☞ Example: a part with a flight count factor of 3,56 means that 100 landings on unpaved airstrips must be counted as 356 landings.

10. Example of aircraft certification process unpaved airstrips

The Pilatus PC-24 (PC-24), an aircraft designed from the outset, for operations on unpaved surfaces

The PC-24 has been designed to accomplish various missions for executive travel, medevac and transport of people and equipment. Some missions are urgent, and cannot wait until the airstrip has dried. Comprehensive tests were therefore conducted to have the PC-24 certified for operation on all unpaved airstrips, in all conditions.

The PC-24 obtained certification for use on unpaved dry dirt, laterite, sand and gravel in 2018., a post-certification test programme was undertaken in 2019 for operations on grass, wet dirt, sand and snow.

Getting to know your airstrip

To test how the PC-24 performs on wet unpaved surfaces one has to know how the airstrip itself reacts to the PC-24. The tests therefore also involved measuring what happens to the surface each time the PC-24 runs over it. How yielding is it? How fast does the water drain away? How long and how deep are the wheel ruts?

While this was going on, the team observed how the PC-24 behaved on the different surfaces. Did the flaps or landing gear accumulate snow or dirt and grass from the airstrips? Did the engines remain clear of debris thrown up from the wheels? These were all important questions in understanding how the PC-24 reacts to ensure that it can cope safely with daily operations on different surfaces in different conditions.

Gravel airstrips in winter

In remote areas such as Northern Canada and Alaska many gravel airstrips are contaminated with snow in winter. A group of engineers and aircraft mechanics travelled out to Kuujjuaq, Canada in March 2019 to test the PC-24 for operation on these surfaces. P02, the second prototype, was equipped with the instrumentation required to measure aircraft performance and with cameras to record snow and slush accumulation on the landing gear, lower fuselage and flaps.

The teams assessed and measured the impact on take-off and landing compared to dry gravel, as well as the effect on aircraft ground handling. How is the steering affected? Is the action of the brakes sufficient? How does the anti-skid system behave? Aircraft visual inspections and analysis of cameras mounted on the aircraft revealed that nothing was ingested by the engines. The results showed that the PC-24 behaved better than predicted on the snow covered gravel airstrip.

170,000 litres of water for a muddy field

The PC-24 has to perform well on wet dirt airstrips in order to operate safely in Africa and the Australian outback.

For the best chance of finding suitable test conditions the team flew to Woodbridge in the UK, where initial dry dirt tests had been conducted in 2018. The tests were carried out in the conditions which might typically occur after a volume of rainfall equivalent to four litres per square metre per hour.

The difficulty lay in finding a means of spraying such a large volume of water in a short time. With the help of a local farmer and a 24 metre (80 foot) farm sprayer we managed to simulate the target conditions using 170,000 litres of water per day.

The PC-24 coped extremely well with this difficult scenario and all wet dirt surface tests were completed successfully.

Grass of all types

The European Aviation Safety Agency (EASA) specifies that tests to obtain certification for operations on grass airstrips must be performed on different types of surfaces. A number of suitable locations were identified and after site inspections, Kunovice in the Czech Republic, Poitiers in France, plus Duxford and Goodwood in Great Britain were selected.

The grass airstrip at Goodwood was at a high standard due to recent work, so it was perfect for tests on dry grass. A series of take-offs and landings were performed in summer 2019 to collect data for certification purposes. The PC-24 was prepared on location, ready and waiting to become the only business jet to be officially approved on the new grass airstrip.

Kunovice, with its two long grass airstrips, a paved airstrip and all the infrastructure required for aircraft tests, proved a perfect location. A detailed set of tests was performed, including single-engine take-offs, engine failure and loss of ground spoilers or anti-skid, all with very good results.

After a number of taxi tests on damp grass, the PC-24 was ready to affront its greatest challenge yet: take-offs and landings on wet grass. The heavy rain provided perfect conditions – and the results turned out perfect. With this conclusive proof of the PC-24's excellent performance on wet grass, the rough field test campaign came to an end.

Mission possible

No significant issues were noted with the PC-24 throughout the tests, on any type of surface. There was no excessive contamination of the flaps or landing gear. No debris was ingested into the engines. The pilots were satisfied with the performance of the PC-24 and all predictions were as expected or even better. With the final tests to expand the scope of operation on unpaved surfaces complete, the PC-24 has proved it is capable of rolling up its sleeves and getting on with the mission in hand, no matter what the location or the conditions.

The PC-24 is now certified for operations on dry and wet airstrips.

11. Unpaved runway treated with engineered base stabilizer

Note: the information provided below is a condensed version of a report published by a consulting engineering firm. The full version is available on request

Background:

The Engineering Firm was contacted by a Multinational Oil & Gas Company (Client) to provide a method of runway stabilization and dust control for an airstrip in Bolivia. The existing problems included loose gravel, the loss of fine material, low visibility, dusty conditions and a slippery surface when wet. Such conditions did not allow for the use of the airstrip during and after heavy rainfall, which significantly limited the Client's plant operations, and created a safety concern.

Critical Aircraft:

Based on the past traffic that the airstrip has had and in light of its ICAO aerodrome reference code of **2-B** – which intrinsically defines the types of aircraft that can operate on this airstrip – it was decided two types of aircraft should be used for reference. One has single-wheel landing gear, and the other has dual-wheel landing gear.

Aircraft	MTOW (Kg)	Landing gear configuration
Cessna 550 and 560 (jet)	7'500	Single
Beechcraft BE 1900D (turboprop)	7'700	Dual

Project Description:

The Client followed the preparation instructions provided by the Engineering Firm and prepared the airstrip prior to the Engineering Firm's Team arrival. The scope of work consisted of the cleaning of the area, contouring, and crowning of the surface to ensure for proper drainage using a grader and the removal of all loose debris, aggregate, soil and rocks from the surface. The preparation was done properly, and two water tanks were made available to allow the surface seal application to be completed very efficiently in 5 days.

Result:

The application of the Surface Seal seals and protects the surface from erosion; loss of fines, cracking and most importantly eliminates dust and allows for increased safety, visibility, and significant reduction in runway maintenance as well as aircraft maintenance.

Additionally, the upgraded airstrip allows for improved aircraft acceleration, greatly reduces damage & maintenance of the aircrafts, as well as improved skid resistance and better pilot visibility.

Physical characteristics of the airstrip after treatment:

Length =	1'800 m
Width =	23 m
Average longitudinal slope =	0.34% Estimated
Transverse slopes =	1.5%
ICAO Reference Code:	**2B,** limited to Visual Flying Rules (VFR) operations
Airstrip surface after treatment:	improved layer, 15 cm thick, compacted to 95% of the maximum laboratory density. It is a coated with stabilizer which is has extensive binding capability and provides a water-resistant surface that is protected from loss of fines, and any erosion, thus the surface remains as a hard long wearing surface.

Conclusion:

- An all weather airstrip surface that is now preserved and protected from erosion and degradation (including, cracks, corrugation, and material loss),

- **Another important result is being able to use the airstrip year round,** The area has a heavy rainy season which causes (untreated) airstrips not to be useable during the rainy season – which is a detriment to the plant operation.,

- The Engineering Company provided the solution with a Surface Seal that maintains an all-weather surface.

- **In addition, this runway has now been approved as a “sealed” category of airstrip and causing Cessna Aircraft to certify the airstrip for Jet landings.**

Application of the surface seal

Cessna jet aircraft on landing on the upgraded surface

12 ATR 42-500 performance analysis: Ouagadougou - Customer Airstrip – Ouagadougou

NOTICE TO READER

INTRODUCTION

Service Providers ZIMEX and EURO OPS, (collectively "**SP**") have performed an in-depth analysis of Customer's tender aiming to provideits subsidiary located Burkina Faso (RFT-SBS-AIR-20220225) ("**SBS**") with up to 50 seat capacity on the Ouagadougou ("**OUA**") – Fada n'Gourma, a public aerodrome with an unpaved 1'500 x 20 m airstrip ("**FNG**") – Customer Mine ("**BGU**") route, currently operated by SP with a 19 seat De Havilland DH6-300 aircraft.

Customer has provided SP with in-house unofficial aerodrome information for the FNG and BGU airstrips, compiled by Customer's Air Ops Operations for internal use.

SP have retained the **ATR42-500** (« **AT45**") (up to 48 seats) as the reference aircraft for the SBS tender evaluations and have initiated an in-depth feasibility study based on Customer's needs and minimal contractual requirements.

A initial comparative analysis between the AT45 and its direct competitor, the De Havilland Canada DHC8-300 (« **DH8C**") (up to 50 seats) has been performed on the network subject to the tenders during the evaluation process in cooperation with the respective manufacturer's Performance Divisions.

The information provided below is a condensed version of the full performance studies and contains the required elements to get acquainted with AT45's performance on the unpaved airstrips of FNG and BGU in DRY condition only. A comparative analysis could not be performed due to slight differences in the calculation methods used by the two manufacturers.

Two separate performance studies were conducted for the AT45 due to the discrepancy between the information provided by Customer and the official Burkina Faso Civil Aviation Authority version regarding the BGU airstrip length.

The DH8C's performance has not been evaluated in depth in the present study.

ANALYZED NETWORK

ROTATION	FROM	TO	REMARKS
1	OUA	FNG	NO FUEL available in FNG
1	FNG	OUA	
2	FNG	BGU	NO FUEL available in BGU
2	BGU	FNG	
3	OUA	BGU	NO FUEL available in BGU
3	BGU	OUA	

AIRSTRIP LENGTH CORRECTIONS

The aircraft performance operating limitations require a length which is enough to ensure that the aircraft can, after starting a take-off, either be brought safely to a stop or complete the take-off safely. For the purpose of discussion it is supposed that the runway, stopway and clearway lengths provided at the airstrip are only just adequate for the reference aircraft requiring the longest take-off and accelerate-stop distances, taking into account its take-off mass, runway characteristics and ambient atmospheric conditions.

In the case of the Customer's BGU airstrip, the reference aircraft used to determine the aircraft (Cessna 208B Caravan) used to determine the characteristics required for the construction of the runway back in 2019 required a reference field length of 750 m (take-off length required at MTOW, sea level, no wind and an outside temperature (OAT) equivalent to ISA (15°C))

The table below shows the corrections that have been applied to determine the airstrip length requirement for a Cessna 208B Caravan operation at BGU

- The actual official airstrip length as declared by ANAC-BF (1'142 m) exceeds the reference aircraft requirements but is insufficient to allow an ATR42-500 operation at its Maximum performance on Customer's required routes as demonstrated hereinafter.

Runway Length Corrections for Elevation, Temperature and Slope

Characteristics	Unit	REFERENCE AIRCRAFT Cessna 208B Caravan (1)	AT42-500 (4)	Formulas
MTOW	kg	3 970	18 600	
Operating Empty Weight	kg	2 073	11 500	
Length	M	12.67	22.67	
Wingspan	M	15.88	24.57	
Basic Take-off distance (2)	M	750	1 165	
Basic Landing Distance (2)	M	570	966	
OMGWS (3)		4.05	4.10	
Airstrip ICAO Code Number		1	2	
Airstrip ICAO Code Letter		B	C	
mplex Aircraft (MTOW > 5.7 Tons) allowed		N/A	NO	
Runway Take-off length corrected for **elevation** (n1)	M	800	1 242	((BL*0.07) * (h/300)) + BLT
Runway Take-off length corrected for **elevation and temperature** (n2)	M	1 008	1 565	((n1*(T-14.025)*0.01)) + n1
Runway Take-off length corrected for **elevation and temperature and slope**	M	1 028	1 597	(n2*P*0.1) + n2
CORRECTED TAKE-OFF LENGTH (rounded)	M	**1 100**	**1 600**	rounded up to the nearest multiple of hundred
Corrected Landing Length	M	608	1 030	((BLL*0.07)*(h/300)) + BLL
CORRECTED LANDING LENGTH (rounded)	M	**700**	**1 100**	rounded up to the nearest multiple of hundred

CUSTOMER's BGU MINE AIRSTRIP

Required Runway Length Correction Calculation

Airstrip Key data for REFERENCE AIRCRAFT			
Base length of runway for take-off	BLT	750	M
Airstrip elevation	h	285	M
Avg temperature hottest month	T	40	°C
Airstrip projected slope	p	0.2	%
Base length of runway for landing	BLL	570	M
ACTUAL official. runway LENGTH		**1 142**	M
ACTUAL runway WIDTH		**32**	M
Bearing Strength	CBR	no info	
ACN - PCN	not measured		
Elevation correction	n1		
Temperature correction	n2		

(1) = Reference aircraft used by ANAC-BF - Data provided by ANAC BF ref. Technical Report Boungou Airstrip 27.03.2019
(2) = Sea level, no wind, OAT ISA. (15° C)
(3) = Outer Main Gear Wheel Span
(4) = Data provided by ATR - ATR42-500 minispecs sheet

OPERATIONAL ASSUMPTIONS

ATR 42-500 - Version Y-48 Operational Assumptions

DESIGN WEIGHTS [kg]

Maximum Take-Off Weight	18 600
Maximum Landing Weight	18 300
Maximum Zero Fuel Weight	17 000
Operating Empty Weight	11 700
Maximum Payload	5 300
Capacity useable fuel (density = 0.803kg/l)	4 603
Passenger + baggage Weight	95
Configuration (seats)	48

TAKE-OFF & LANDING ASSUMPTIONS

Airfield temperature	ISA+15 [°C]
Airfield wind 0	[kts]
Runway condition	DRY
Obstacles	Detailed obstacle data
Data source	ACFT Perfo

RESERVE POLICY

Contingency fuel	5 % trip fuel
Holding	30 min
Fuel for diversion	Detailed in En-Route Performance

FLIGHT PROFILE

Max. Cruise

Climb	160 KIAS
Cruise	Max. Cruise
Descent	250 KIAS

ALLOWANCES

	Time[min]	Fuel. [kg]
Start-Up & Taxi-Out	6	12
Take-Off and initial climb	1	17
Approach and landing	2	20
Taxi-In	4	12

EN-ROUTE ASSUMPTIONS

Take-Off & Landing conditions
From best runway

En-Route distances	GCD+5,3[%]
En-Route temperature	ISA+15 [°C]
En-Route wind	No Wind

AIRFIELD DATA I (Customer airstrip length 1’142m according to official ANAC-BF statement)

Name	IATA Code	ICAO Code	Rwy ID	Surface Type	Elev [ft]	Slope [%]	Width [m]	TORA [m]	TODA [m]	ASDA [m]	LDA [m]	Refueling
OUAGADOUGOU	OUA	DFFD	04	Normal	1 034	-0.53	45	3 013	3 263	3 013	3 013	YES
OUAGADOUGOU	OUA	DFFD	22	Normal	981	0.53	45	3 013	4 013	3 013	3 013	YES
Customer (Private)	BGU		06	**Dry unpaved with CBR less than 15**	932	0.00	32	1 142 ANAC-BF Version	1 142	1 142	1 142	NO
Customer (Private)	BGU		24	**Dry unpaved with CBR less than 15**	932	0.00	32	1 142 ANAC-BF Version	1 142	1 142	1 142	NO
Fada N'Gourma	FNG		04	Dry unpaved with CBR less than 15	1 007	0.00	20	1 500	1 500	1 500	1 500	NO
Fada N'Gourma	FNG		22	Dry unpaved with CBR less than 15	1 015	0.00	20	1 500	1 500	1 500	1 500	NO

AIRFIELD TAKE-OFF PERFORMANCE I (Customer airstrip length1'142m according to official ANAC-BF statement)

AIRPORT			RUNWAY			TAKE-OFF							
City	IATA	ICAO	Rwy ID	Elev [ft]	Slope [%]	ISA [°C]	OAT [°C]	Wind [kts]	Rwy Cond	TODA [m]	RTOW [kg]	Power	Limit
OUAGADOUGOU	OUA	DFFD	04	1 034	-0.53	15.0	27.9	0	Dry	3 263	18 600		STRUCTURE - VMC
OUAGADOUGOU	OUA	DFFD	22	981	0.53	14.9	27.9	0	Dry	4 013	18 600		STRUCTURE - VMC
Customer (private)	BGU		06	932	0.00	15.0	28.2	0	Dry	1 142	15 503		RUNWAY - VMC
Customer (private)	BGU		24	932	0.00	15.0	28.2	0	Dry	1 142	15 503		RUNWAY - VMC
Customer (private)	BGU		06	932	0.00	15.0	28.2	0	Dry	1 142	16 310	RTO	RUNWAY - VMC
Customer (private)	BGU		24	932	0.00	15.0	28.2	0	Dry	1 142	16 310	RTO	RUNWAY - VMC
Fada N'Gourma	FNG		04	1 007	0.00	15.0	28.0	0	Dry	1 500	18 600		STRUCTURE - STRUCTURE
Fada N'Gourma	FNG		22	1 015	0.00	15.0	28.0	0	Dry	1 500	18 600		STRUCTURE - STRUCTURE

AIRFIELD LANDING PERFORMANCE I (Customer airstrip length 1'142m according to official ANAC-BF statement)

AIRPORT			RUNWAY			LANDING						
City	IATA Code	ICAO Code	Rwy ID	Elev. [ft]	Slope [%]	ISA [°C]	OAT [°C]	Wind [kts]	Rwy Cond	LDA [m]	RLW [kg]	Limit
OUAGADOUGOU	OUA	DFFD	04	1 034	-0.53	15.0	27.9	0	Dry	3 013	18 300	STRUCTURE
OUAGADOUGOU	OUA	DFFD	22	981	0.53	14.9	27.9	0	Dry	3 013	18 300	STRUCTURE
Customer (private)	BGU		06	932	0.00	15.0	28.2	0	Dry	1 142	18 300	STRUCTURE
Customer (private)	BGU		24	932	0.00	15.0	28.2	0	Dry	1 142	18 300	STRUCTURE
Fada N'Gourma	FNG		04	1 007	0.00	15.0	28.0	0	Dry	1 500	18 300	STRUCTURE
Fada N'Gourma	FNG		22	1 015	0.00	15.0	28.0	0	Dry	1 500	18 300	STRUCTURE

EN-ROUTE PERFORMANCE I - Distance, Diversion and Weights

(Customer airstrip length 1’142m according to official ANAC-BF statement)

SECTOR									DIVERSION			WEIGHTS	
Rot,	From	To	Dist. [NM]	ISA [°C]	Wind [kts]	FL	Flight Technique	Power	To	Dist. [NM]	FL	TOW [kg]	LW [kg]
A	OUA	BGU	174	15	0	190	Max. Cruise		OUA	174		18 559	18 049
	BGU	OUA	174	15	0	200	Max. Cruise		OUG	90	140	15 503	15 015
D	OUA	BGU	174	15	0	190	Max. Cruise		OUA	174	200	18 264	17 757
	BGU	OUA	174	15	0	200	Max. Cruise		OUG	90	140	15 503	15 015
	BGU	OUA	174	15	0	200	Max. Cruise	RTO	OUG	90	140	16 310	15 818
B	OUA	FNG	112	15	0	130	Max. Cruise		OUA	112		18 324	17 960
	FNG	OUA	112	15	0	140	Max. Cruise		OUG	90	120	17 930	17 569
E	OUA	FNG	112	15	0	150	Max. Cruise		OUA	112	140	17 981	17 621
	FNG	OUA	112	15	0	140	Max. Cruise		OUG	90	120	17 930	17 569
C	OUA	BGU	174	15	0	190	Max. Cruise		OUA	174		18 600	18 090
	BGU	FNG	62	15	0	100	Max. Cruise		OUG	187		15 503	15 278
	FNG	OUA	112	15	0	140	Max. Cruise		OUG	90	120	17 930	17 569
F	OUA	BGU	174	15	0	190	Max. Cruise		OUA	174	200	18 264	17 757
	BGU	FNG	62	15	0	100	Max. Cruise		OUG	187	220	15 503	15 278
	BGU	FNG	62	15	0	100	Max. Cruise	RTO	OUG	187	220	16 310	16 083
	FNG	OUA	112	15	0	140	Max. Cruise		OUG	90	120	17 930	17 569

EN-ROUTE PERFORMANCE I – Fuel, Time and Payload

(Customer airstrip length 1’142m according to official ANAC-BF statement)

SECTOR			FUEL			TIME		PAYLOAD				
Rot	From	To	Block [kg]	Reserve [kg]	Total [kg]	Flight [hh:mm]	Block [hh:mm]	Max PL [kg]	Limitation	PAX	Load Factor (%)	Extra [kg]
A	OUA	BGU	540	0	1 577	00:45	00:55	5 300	MaxPL	48	100%	740
	BGU	OUA	518	531	1 037	00:43	00:53	2 784	RTOW	29	60%	29
D	OUA	BGU	538	757	1 282	00:44	00:54	5 300	MaxPL	48	100%	740
	BGU	OUA	518	531	1 037	00:43	00:53	2 784	RTOW	29	60%	29
	BGU	**OUA**	**522**	**543**	**1 053**	**00:43**	**00:53**	**3 575**	**RTOW**	**37**	**77%**	**60**
B	OUA	FNG	394	0	1 342	00:30	00:40	5 300	MaxPL	48	100%	740
	FNG	OUA	391	569	948	00:30	00:40	5 300	MaxPL	48	100%	740
E	OUA	FNG	390	620	998	00:30	00:40	5 300	MaxPL	48	100%	740
	FNG	OUA	391	569	948	00:30	00:40	5 300	MaxPL	48	100%	740
C	OUA	BGU	540	0	1 744	00:45	00:55	5 174	MTOW,RTOW	48	100%	614
	BGU	FNG	256	0	1 204	00:17	00:27	2 617	RTOW	27	56%	52
	FNG	OUA	391	569	948	00:30	00:40	5 300	MaxPL	48	100%	740
F	OUA	BGU	538	757	1 282	00:44	00:54	5 300	MaxPL	48	100%	740
	BGU	FNG	256	727	971	00:17	00:27	2 850	RTOW	30	63%	0
	BGU	**FNG**	**257**	**745**	**991**	**00:18**	**00:28**	**3 637**	**RTOW**	**38**	**79%**	**27**
	FNG	OUA	391	569	948	00:30	00:40	5 300	MaxPL	48	100%	740

AIRFIELD DATA II (Customer airstrip length 1'340m according to Customer statement)

Name	IATA Code	ICAO Code	Rwy ID	Surface Type	Elev [ft]	Slope [%]	Width [m]	TORA [m]	TODA [m]	ASDA [m]	LDA [m]	Refueling
OUAGADOUGOU	OUA	DFFD	04	Normal	1 034	-0.53	45	3 013	3 263	3 013	3 013	YES
OUAGADOUGOU	OUA	DFFD	22	Normal	981	0.53	45	3 013	4 013	3 013	3 013	YES
Customer (Private)	BGU		06	**Dry unpaved with CBR less than 15**	932	0.00	32	**1 340 Customer Version**	**1 340**	**1 340**	**1 340**	NO
Customer (Private)	BGU		24	**Dry unpaved with CBR less than 15**	932	0.00	32	**1 340 ANAC-BF Version**	**1 340**	**1 340**	**1 340**	NO
Fada N'Gourma	FNG		04	Dry unpaved with CBR less than 15	1 007	0.00	20	1 500	1 500	1 500	1 500	NO
Fada N'Gourma	FNG		22	Dry unpaved with CBR less than 15	1 015	0.00	20	1 500	1 500	1 500	1 500	NO

AIRFIELD TAKE-OFF PERFORMANCE II (Customer airstrip length 1'340m according to Customer statement)

AIRPORT			RUNWAY			TAKE-OFF							
City	IATA	ICAO	Rwy ID	Elev [ft]	Slope [%]	ISA [°C]	OAT [°C]	Wind [kts]	Rwy Cond	TODA [m]	RTOW [kg]	Power	Limit
OUAGADOUGOU	OUA	DFFD	04	1 034	-0.53	15.0	27.9	0	Dry	3 263	18 600		STRUCTURE - VMC
OUAGADOUGOU	OUA	DFFD	22	981	0.53	14.9	27.9	0	Dry	4 013	18 600		STRUCTURE - VMC
Customer (private)	BGU		06	932	0.00	15.0	28.2	0	**Dry**	**1 340**	**17 735**		RUNWAY - VMC
Customer (private)	BGU		24	932	0.00	15.0	28.2	0	**Dry**	**1 340**	**27 735**		RUNWAY - VMC
Customer (private)	BGU		06	932	0.00	15.0	28.2	0	**Dry**	**1 340**	**18 111**	**RTO**	RUNWAY - VMC
Customer (private)	BGU		24	932	0.00	15.0	28.2	0	**Dry**	**1 340**	**18 111**	**RTO**	RUNWAY - VMC
Fada N'Gourma	FNG		04	1 007	0.00	15.0	28.0	0	Dry	1 500	18 600		STRUCTURE - STRUCTURE
Fada N'Gourma	FNG		22	1 015	0.00	15.0	28.0	0	Dry	1 500	18 600		STRUCTURE - STRUCTURE

AIRFIELD LANDING PERFORMANCE II (Customer airstrip length 1'340m according to Customer statement)

AIRPORT			RUNWAY			LANDING						
City	IATA Code	ICAO Code	Rwy ID	Elev. [ft]	Slope [%]	ISA [°C]	OAT [°C]	Wind [kts]	Rwy Cond	LDA [m]	RLW [kg]	Limit
OUAGADOUGOU	OUA	DFFD	04	1 034	-0.53	15.0	27.9	0	Dry	3 013	18 300	STRUCTURE
OUAGADOUGOU	OUA	DFFD	22	981	0.53	14.9	27.9	0	Dry	3 013	18 300	STRUCTURE
Customer (private)	BGU		06	932	0.00	15.0	28.2	0	Dry	**1 340**	18 300	STRUCTURE
Customer (private)	BGU		24	932	0.00	15.0	28.2	0	Dry	**1 340**	18 300	STRUCTURE
Fada N'Gourma	FNG		04	1 007	0.00	15.0	28.0	0	Dry	1 500	18 300	STRUCTURE
Fada N'Gourma	FNG		22	1 015	0.00	15.0	28.0	0	Dry	1 500	18 300	STRUCTURE

EN-ROUTE PERFORMANCE II - Distance, Diversion and Weights (Customer airstrip length 1'340 m according to Customer statement)

SECTOR									DIVERSION			WEIGHTS	
Rot,	From	To	Dist. [NM]	ISA [°C]	Wind [kts]	FL	Flight Technique	Power	To	Dist. [NM]	FL	TOW [kg]	LW [kg]
A	OUA	BGU	174	15	0	190	Max. Cruise		OUA	174		18 600	18 090
	BGU	OUA	174	15	0	200	Max. Cruise		OUG	90	140	17 735	17 227
D	OUA	BGU	174	15	0	190	Max. Cruise		OUA	174	200	18 264	17 757
	BGU	OUA	174	15	0	200	Max. Cruise		OUG	90	140	18 080	17 569
	BGU	OUA	174	15	0	200	Max. Cruise	RTO	OUG	90	140	18 324	17 960
B	OUA	FNG	112	15	0	130	Max. Cruise		OUA	112		17 930	17 569
	FNG	OUA	112	15	0	140	Max. Cruise		OUG	90	120	17 981	17 621
E	OUA	FNG	112	15	0	150	Max. Cruise		OUA	112	140	17 930	17 569
	FNG	OUA	112	15	0	140	Max. Cruise		OUG	90	120	18 600	18 090
C	OUA	BGU	174	15	0	190	Max. Cruise		OUA	174		17 735	17 506
	BGU	FNG	62	15	0	100	Max. Cruise		OUG	187		17 930	17 569
	FNG	OUA	112	15	0	140	Max. Cruise		OUG	90	120	18 264	17 757
F	OUA	BGU	174	15	0	190	Max. Cruise		OUA	174	200	18 013	17 784
	BGU	FNG	62	15	0	100	Max. Cruise		OUG	187	220	17 930	17 569
	BGU	FNG	62	15	0	100	Max. Cruise	RTO	OUG	187	220	18 600	18 090
	FNG	OUA	112	15	0	140	Max. Cruise		OUG	90	120	17 735	17 227

EN-ROUTE PERFORMANCE II – Fuel, Time and Payload (Customer airstrip length 1'340m according to Customer statement)

SECTOR			FUEL			TIME		PAYLOAD				
Rot	From	To	Block [kg]	Reserve [kg]	Total [kg]	Flight [hh:mm]	Block [hh:mm]	Max PL [kg]	Limitation	PAX	Load Factor (%)	Extra [kg]
A	OUA	BGU	540	0	1 630	00:45	00:55	5 288	MaxPL	48	100%	728
	BGU	OUA	539	563	1 090	00:43	00:53	4 964	RTOW	48	100%	404
D	OUA	BGU	538	757	1 282	00:44	00:54	5 300	MaxPL	48	100%	740
	BGU	OUA	541	569	1 098	00:43	00:53	5 300	RTOW	48	100%	740
	BGU	OUA	394	0	1 342	00:43	00:53	5 300	RTOW	48	100%	740
B	OUA	FNG	391	569	948	00:30	00:40	5 300	MaxPL	48	100%	740
	FNG	OUA	390	620	998	00:30	00:40	5 300	MaxPL	48	100%	740
E	OUA	FNG	391	569	948	00:30	00:40	5 300	MaxPL	48	100%	740
	FNG	OUA	540	0	1 747	00:30	00:40	5 171	MaxPL	48	100%	611
C	OUA	BGU	259	0	1 207	00:45	00:55	4 846	MTOW,RTOW	48	100%	286
	BGU	FNG	391	569	948	00:17	00:27	5 300	RTOW	48	100%	740
	FNG	OUA	538	757	1 282	00:30	00:40	5 300	MaxPL	48	100%	740
F	OUA	BGU	259	784	1 031	00:44	00:54	5 300	MaxPL	48	100%	740
	BGU	FNG	391	569	948	00:17	00:27	5 300	RTOW	48	100%	740
	BGU	FNG	540	0	1 630	00:18	00:28	5 288	RTOW	48	100%	728
	FNG	OUA	539	563	1 090	00:30	00:40	4 964	MaxPL	48	100%	404

Comparative performance on the 2 different indicated BGU airstrip length

FROM	TO	1'142 M Airstrip Length		1'340 M Airstrip length	
		Avlb Pax load factor	Additional payload	Avlb Pax load factor	Additional payload
OUA	BGU	100 %	740 Kg	100 %	728 Kg
BGU	OUA	60 % (29 pax)	29 Kg	100 %	404 Kg
OUA	BGU	100 %	614 Kg	100 %	286 Kg
BGU	FNG	56 % (27 pax)	52 Kg	100 %	740 kg
FNG	OUA	100 %	740 Kg	100 %	740 Kg

13 CONCLUSION

This report is based on the various information that has been collected by the authors from various sources since the issue of the Customer's tender ref. RFT-SBS-AIR-20220225 (the Tender) on 25.02.2022 regarding the operation of complex 40-50 seat aircraft on unpaved airstrips.

Euro Ops, Zimex and BCC have, collectively and individually, identified various issues set forth in the Tender documents that require clarification, in particular those pertaining to the feasibility of operating complex aircraft operations on unpaved airstrips of BGU and FNG that the Customer intends to serve.

Tender documents and other information sources made available to the authors show discrepancies e.g., between the official information provided by the Burkinabe Civil Aviation Authorities and those obtained from the Customer.

The official statements released by the Authorities e.g., regarding the actual length of the BGU airstrip prevailed over the other information. However, all ATR42-500 performance calculations herein exposed have been carried out on both airstrip length made available to the authors.

The list of findings below has been drawn up on the basis of the elements in the possession of the authors at the time of publication of this document. It is likely that more discoveries will be added as new facts are brought to the attention of the authors and the Working Group and will result in revisions to this document.

An analysis of the effective costs of unscheduled maintenance is also planned on the basis of feedback from an operator currently carrying out missions on unpaved terrain using ATR72-500 on behalf of NGO, leading to an amendment to this version of the document

A more detailed analysis of the operational and financial performance resulting from the operation of the proposed aircraft type as well as a feasibility study concerning the BGU (and possibly the FNG airstrip) surface upgrade by applying a surface seal will be carried out in the event that:

- **the Tender is awarded to the Zimex-Air Sarada-Euro Ops joint offer, or**
- **the Customer expresses the interest of developing a cooperation with the Working Group in order to upgrade its BGU airstrip and to further analyze the feasibility of operating complex aircraft to cover his air transportations requirements.**

14. Findings:

- **BGU airfield certification supporting documents:** the documents in the hands of the Working Group pertaining to the BGU airstrip are:

  - Decree N° 2019-0525 promulgating the law N° 013-2019/AN dated 30.04.2019 on the civil aviation code in Burkina Faso,
  - Technical investigation report for the construction of a private airstrip issued by ANAC-BF dated 27.03.2019,
  - Authorization to create and to use an unpaved airstrip on the premises of Customer's mining concession for private use only delivered by the Ministry of Transportation dated 25.09.2020,
  - Customer's internal BGU Airstrip Information Sheet (document not endorsed by ANAC-BF)
  - No information available as to measured CBR and ACN-PCN values

- **BGU airstrip data and certification:** categorization as per the Authorization delivered by the Ministry of Transportation
  - The Cessna 208B Caravan has been used as reference aircraft for the certification of the airstrip,
  - BGU airstrip has been granted ICAO 1B classification,
  - ICAO 1B reference code is not suitable for a complex aircraft operation, including for the ATR42-500, which requires ICAO 2C,
  - The nature of its airstrip is laterite,
  - The ATR42-500 is certified to operate on DRY laterite airstrips only,
  - The official dimensions of the airstrip shown in the Ministry of Transportation's authorization are 1'142 m X 32 m and are contradicted by Customer's assertion of 1'340 m X 32 m,
  - The ATR 42-500 is. only able to operate on routes required by Customer 1'142 m X 32 M with severe payload restrictions,
  - The ATR42-500 operates on routes required by Customer without payload restrictions on 1'340 m X 32 m under normal operating conditions.

- **FNG airfield certification supporting documents:** the official documents in the hands of the Working Group pertaining to the FNG airstrip are:
  - Customer's internal FNG Airstrip Information Sheet, (document not endorsed by ANAC-BF)
  - No information available as to measured CBR and CAN-PCN values.

- **FNG airfield information supporting documents:** the documents in the hands of the Working Group pertaining to the BGU airstrip are:
  - Decree N° 2019-0525 promulgating the law N° 013-2019/AN dated 30.04.2019 on the civil aviation code in Burkina Faso,
  - ASECNA Burkina Faso List of Aerodromes and Runways effective date 24.03.2022,
  - Customer's internal Airstrip Information Sheet. (Document not endorsed by ANAC-BF)

- **FNG airstrip data and certification:**
  - No information as to reference aircraft used for the certification of the airstrip,
  - No information as to the ICAO classification,
  - The nature of its airstrip is laterite,
  - The ATR42-500 is certified to operate on DRY laterite airstrips only,
  - The official dimensions of the airstrip shown in the ASECNA charts are 1'500 m X 20 m and match with Customer provided information assertion,
  - The ATR 42-500 is able to operate routes required by Customer on available airstrip length with no payload restrictions under normal operating conditions,
  - The ATR42-500 is able to operate routes required by Customer on available airstrip width of upon embodiment of ATR Special Operations procedures – Narrow runways.

- **Consequences to the operation and its costs in case of status quo on the condition of the BGU and FNG airstrip**
  - An ATR42-500 operation on the customer's airstrip surface in its current state would have the following consequences:
    - *Potential safety hazard,*
    - *Severe disturbances of operational reliability, in particular during the rainy season,*
    - *Significantly increased operating costs due to the creation of provisions for unplanned maintenance costs and higher maintenance reserves.*

- **Availability of ARFF at BGU and FNG airstrips**

    - On-site availability of ARFF is mandatory at the airfield in case or commercial operations performed by a complex aircraft. No information available as to compliance with this requirement at either BGU or FNG

- **Impact of unscheduled maintenance costs and additional maintenance reserves**

- No information available at time of publication of the present report. A revision shall be released upon receipt and analysis of relevant facts and figures from third party ATR operator

- **Impact of airstrip stabilization and upgrade**

    - Improved operating safety conditions,
    - Certification of the airstrip as “paved” or “sealed”, (subject to approval by Civil Aviation Authorities)
    - All year-round unrestricted airstrip operational availability under both DRY and WET conditions,
    - Reduction of dust / FOD ingestions,
    - Reduction of unscheduled maintenance costs and additional maintenance reserve provisions,
    - No requirement for gravel protections on aircraft,
    - Reduced airstrip maintenance,
    - Enhanced airstrip protection from erosion and degradation.

14 RECOMMENDATIONS

The authors of the presentation and the members of the Working Group recommend that:

☒ The Customer joins the Working Group in its capacity as private airfield owner and manager; and,

☒ The Customer evaluates the feasibility of upgrading and stabilizing the BGU airstrip; and,

☒ The Customer and the Working Group organize a site assessment at the BGU airstrip; and,

☒ The Working Group and the Customer liaise with the Burkinabe Ministry of Transportation and ANAC-BF for validation of the BGU airstrip process; and,

☒ The Customer approaches Ministry of Transportation and ANAC-BF for evaluation of including of FNG airstrip in the upgrading and stabilization process,

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