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WEATHER CONDITIONS AND ITS EFFECTS ON UAS

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ABSTRACT

To study the flight performance of UAS under adverse weather conditions including temperature, humidity, fog, precipitation, sturdy winds an experimental UAS was developed. The experimental flights of UAS were tested in different weather conditions including normal to heavy rain, hot to cold temperature, calm and windy situation, humidity and fog. Flights were fully autonomous from take off to landing. Sensors were coordinated on board the UAS during the flight. To acknowledge better the effects of adverse weather on flight performance, the UAS altitude data and UAS power consumption data were correlated with the measured results of atmosphere parameters. The experimental portion of the flight had fixed geo-location and trajectories in the designed mission. In the experimental study it has shown that ice accretion reduces the performance of UAS and increases higher power consumption. Temperature also affects the flight performance of UAS. Hot temperature reduces lift while cold temperature increases the lift. Buildup of ice on UAS propeller reduces thrust and lift and increases drag, this resulted more power consumption and decreasing speed. Mostly ice forms on forefront of main wing. Strong winds are mainly responsible for turbulence, it was discovered that this was the second highest situation in which system loses power highly and it is also responsible for structural damage of the system. The another major weather condition that affects UAS is fog .The fog is made up of small water droplets , this causes propeller to stop spinning and the UAS can plummet to the ground. The findings derived from the present study focus on the importance and necessity of developing effective strategies to ensure safer and more reliable UAS operations under adverse weather conditions.

Keywords: Flight Performance, Adverse Weather Effect, Unmanned Aircraft System.

I. INTRODUCTION

The idea of unmanned aerial object is older than manned flights. Around 200AD Chinese used hot air balloons to fly over the enemies in the dark. At the time of civil war, in the United States Union and Confederate forces used balloons to supply explosive or to explode them. The prominent reason behind the concept of unmanned aerial object was not to jeopardize human life with experimental objects. The names mainly describe a flying machine with no a pilot on board that are aerial torpedo, radio controlled vehicle, remotely piloted vehicle, autonomous controlled vehicle, unmanned aircraft system, remote controlled vehicle. The phrase unmanned aircraft system (UAS) was first acquired by the United States Department of Defense (DoD) and the United States Federal Aviation Administration (FAA) in 2005 as claimed by their unmanned aircraft system guideline 2005-2030. The British Civil Aviation Authority and The International Civil Aviation Organization also adopted this term. This term highlights the prominence of other components than the aircraft. It includes elements such as ground control situation, data links and other support equipment.

Unmanned Aircraft System (UAS):-

An UAS is called unmanned aircraft system, that means no human pilot, crew, or passenger on board.

UAS mostly have following components:-

1. A Control System which can be autonomous or human operated remote system.
2. Command Control and Communication System.
3. An Unmanned Aerial Vehicle.
4. A payload specific for intentional operation or application, which can be any kind of equipment, for instance, advance camera or sensors to collect data for analysis.

Generally, UAS are known with the names:-

Unmanned Aerial System (UAS), Unmanned Aerial Vehicle (UAV), Remotely Piloted Aircraft System (RPAS).

The phrase Unmanned Aircraft System (UAS) was acquired by the United States Department of Defense (DoD) and the United States Federal Aviation Administration (FAA) in 2005 as per claimed their Unmanned Aircraft

System guideline 2005-2030. The British Civil Aviation authority and the international Civil Aviation Organization (ICAO) acquired this term, also utilize in the European Union's Single –European Sky (SES) Air Traffic Management (ATM) Research (Sesar Joint Undertaking) roadmap for 2020. This term puts the more pressure and makes the importance of other elements more clear than the only aircraft. Unoccupied and uninhabited are the terms that are occasionally used as gender neutral alternatives to "unmanned". As other aircraft on the basis of design layout for instance type of engine, weight, flight altitude, operation autonomy, operational rate etc UAS can be classified :-

1. Based on weight:-

We can classify the drones into 5 categories on the bases of their weight:-

*NANO (250 g)

*MAV (Micro Air Vehicles)(250g-2kg)

*Small UAV(SUAV)(2-25kg)

*Medium (25-150kg)

*Large (more than 150 kg)

2. Based on the altitude:-

For industrial affairs such as Parc Aberpoth Unmanned System Form ; UAS classification have been used on the basis of their altitude:-

* Hand –held 2,000ft(600m) altitude, about 2km range.

* Close 5,000ft(1500m) altitude , up to 10km range .

*NATO type 10,000ft(3,000m) altitude, up to 50km range.

*Tactical 18,000ft (5, 5000m) altitude, about 180km range.

* MALE (medium altitude, long endurance) approximately 30,000ft (9,000m) and range over 200km.

* HALE (high altitude ,long endurance) over 30,000ft (9,100m)and indefinite range .

*Hypersonic high speed, supersonic (Mach 1.5) or hypersonic (Mach 5+) 50,000ft (15,200) or suborbital altitude, range over 200km.

*Orbital low earth orbit (Mach 25+)

*CIS Lunar Earth –Moon transfer.

*Computer Assisted Carrier Guidence System(CACGS) for UAV.

3. Based upon the degree of autonomy:-

ICAO(International Civil Aviation Organization) classifies unmanned aircraft as remotely piloted aircraft or fully autonomous. Few UAV offers intermediate degree of autonomy. For example, an aircraft which is remotely operated in multiple cases but it has autonomous return –to-base operation. Some aircraft types, including manned aircraft transformed into unmanned or voluntary piloted UAVs

- Based on composite criteria:-

This classification is based on maximum altitude, weight and speed of UAV component.

II. METHODOLOGY

FLIGHT PERFORMANCE OF UAS:-

Performance term mainly describes the ability of an aircraft to accomplish certain things. Flight performance of UAS focuses on three main areas: flight mechanics and propulsion integration, UAS design and design methodologies. Design of UAS mainly focuses on the design of UAV's in three sections – vehicle design, autopilot design and ground system design. UAS currently needs extensive human involvements to accomplish successful mission operations.

*Existing UAV system interfaces provide hardly any support for collaboration between for operators to collaborate with information consumer or remote operators.

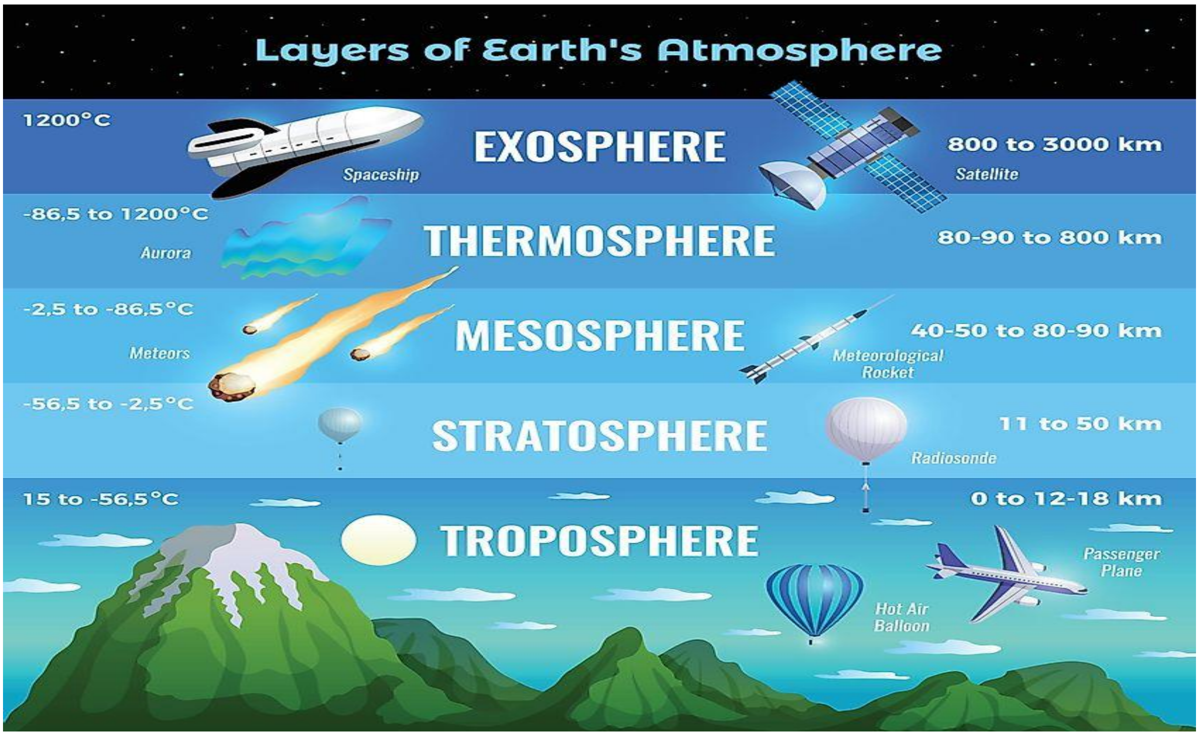
*The application of UAV's continually increasing in civilian operations and military, this dearth of support for collaboration will possibly become significant limitation of existing UAV system.

* To introduce worthwhile collaboration support to UAV system interfaces, it is mendetory to understand and be able to derive system design requirements address, the necessary group interactions that occur in UAV test environments.

TYPES OF WEATHER CONDITIONS:-

Earth's atmosphere has a serious of layers and each layer has its own specific characteristics. These layer names are :-

1. Troposphere
2. Stratosphere
3. Mesosphere
4. Thermosphere
5. Exosphere



The exosphere is the most outer layer of the atmosphere that fades away into the interplanetary space. The first layer of earth's atmosphere from the bottom is troposphere. This layer contains 75%of the total mass of the planetary atmosphere and 99% of total mass of water vapor and aerosols. In this layer most of the weather phenomenon occurs. The general height of the troposphere from the planetary surface of the earth is 13KM in the tropics, 11.5KM in the middle latitudes of the polar-regions in winter, so the general height of the troposphere is about to 10 KM above sea level. Mostly commercial jets fly above or below troposphere, but this layer offers supreme flying conditions for numerous reasons. The troposphere is the most low layer of earth's atmosphere, this is where most of the weather phenomenon occurs, but this layer also offers the most ideal conditions for the flying. First ideal condition that troposphere offers is that , this provides minimal drag or resistance for commercial jets, if commercial jets fly below the troposphere they will likely to burn more fuel because there is more drag at lower altitudes.

This layer contains most of the weather situation including rain, snow, wind, frost, fog, thunderstorms, hail, cyclone, tornados, derechos, microburst, ice storms. Weather forecast plays a major role concerning fly or to stay grounded. However weather conditions highly affects the aviation and the effects are undesirable. Heavy rain challenges the visibility critically and it also increases the drag on the aircraft wings, disturbs the smooth airflow, it causes decrement in lift. Same phenomenon occurs is hail. All aircrafts are affected by fog, it challenges visibility, which causes delay in flights. Mostly commercial aircrafts are equipped with autopilot system that helps to land the plane in zero visibility. In many modern airplanes automatic landing equipments

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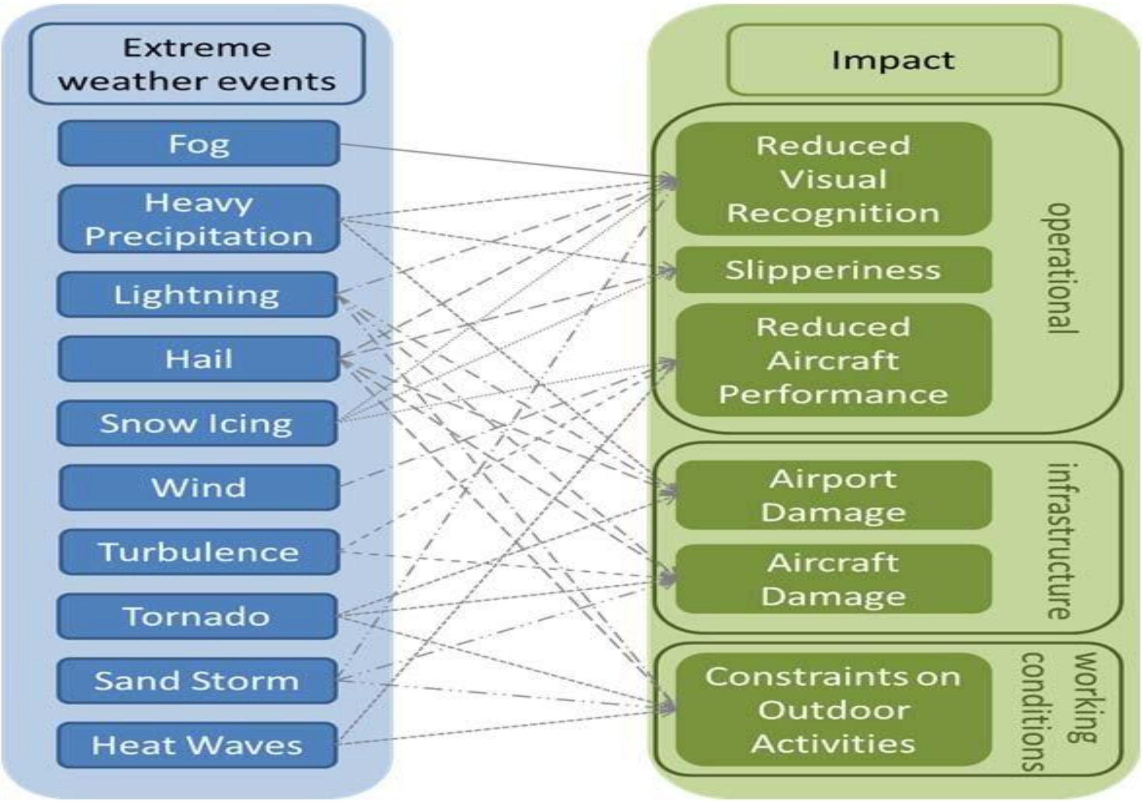
are installed so they can land even in the densest fog. Flying in normal wind condition also affects the aircraft, the speed of wind and direction makes flight times more different than usual. Tailwinds which flows in the direction of the aircraft reduces the drag and increases its speed decreases , the time needed to reach it's destination while headwinds has the opposite impact on the aircraft , it increases the drag due to this aircraft consumes more power and the speed lessens.



ADVERSE WEATHER FOR UAS:-

Weather conditions which make flight of manned and unmanned aircraft difficult and challenge the ability of flight are usually called adverse weather conditions. Adverse weather conditions such as extremely high/low temperature, rain, snow, ice, strong winds, fog, thunderstorms, lightning, hail, tornadoes, hurricanes, have negative effects on the performance of manned and unmanned aircraft. For instance, specifically for UAS, freezing temperature drains the battery life, high wind and ice formation on the propellers highly increase the risk for crash. Hazards caused by these inappropriate weather conditions have the capability to cause loss of control, loss of communication and diminished aerodynamic performance, resulting in severe damage or loss of aircraft and putting people in dangerous situation. The general rule is that one should avoid flying in severe weather, since if lost control, the drone can pose a greater risk to people and objects on the ground. Therefore, one must have extra knowledge about how the weather and meteorological conditions affect your drone and flight. Just like seasons a drone pilot may encounter poor visibility in worse surroundings, that is a reason to fly more cautiously or not at all in adverse weather conditions.

Severity	Hazards	Weather types
Moderate	*Reduced visibility	* Fog *HAZE *Glare *Cloud cover
Adverse	*Loss of communication *Loss of control *Loss of command	*Wind and turbulence *Rain *Solar storms

	*Diminished aerodynamic Performance *Reduced operator effectiveness	*Temperature and humidity *Snow and ice
SEVERE	*Severe damage or loss of Aircraft *Unacceptable risk to operator And personal	*Lightning *Hail *Tornadoes *Hurricanes

COMPONENTS OF UAS (AFFECTED BY WEATHER DIRECTLY)

These are the elements of the UAS that are directly affected by the weather conditions. In these kind of operations a fixed wing aircraft can utilize its aerodynamic design in an efficient way compared to helicopter or multi-rotor, that are more complicated and spend a lot of energy in staying airborne.

1. Frame: This is basically a structure in which all the other parts fit in. It works as a skeleton in which different components are placed in such a manner that they uniformly distribute the centre of gravity. In wind conditions if drone is carrying any kind of load for specific operation, the center of gravity may shift as the weight distribution on the drone changes. Because of this drone can lose the balance and in worst case it can crash. Generally, clouds are not considerable as hazard for the UAS flight. However in the history of the aviation across the world, aircrafts have been damaged even broken when encountering sever clouds. Some clouds are direct danger, they have the capacity to rip apart even a vast flying body. If you are flying a drone through the sever cloud it can damage the body or the frame of drone.

2. Motors: Motors are necessary for the propeller's rotation. This increase thrust force for propelling the drone. The numbers of the motors should be the same as the number of propellers. The motors are also fitted in a way such that they are easily rotated by the controller. Their rotation increases the drone control when it comes to direction. For the efficiency of drone, it is mandatory to choose the right motor. Motor is dramatically affected by the different kind of weather conditions. Strong winds pushes drone in the direction in which it doesn't want to go, in this situation more stability is needed than usual and for this motors have to work harder . For safety purpose it is advisable not to fly a drone when the wind speed exceeds the speed of the drone. For DJI Phantom this 36 MPH, for DJI Inspire, this is 46MPH.

3. Electronic speed and controller (ESC): This is basically an electronic control board that varies the motor's speed. It plays the part of a dynamic brake. The component helps the ground pilot to approximate the height at which the drone is running in. This is achieved by all the motors altitude is associated with power drain from the power reservoirs. Precipitation, rain, snow, fog or humidity can damage this electronic control board , which can impact pilot ability to control the drone and lead to physical damage to the drone.

4. Propellers: Propellers are clove like blade designed to create a difference in air pressure. When propellers are in motion, they cut through the air to create difference in pressure between the top and the bottom of the rotors. The top side is specify by low pressure as compared to the bottom that cause the drone to lift into the air. In hot weather prevailing density altitude increases, which means the air density becomes lower , because of this the efficiency of propeller reduces and to work properly and to generate more lift propellers have to work more harder . Different drones have different capacity to withstand with cold temperature. If you fly a drone in cold temperature, there is always risk of ice buildup on the propellers. Ice buildup on the propellers have major consequences. As the propeller freeze, it won't be able to produce thrust, it can cause the drone to crash. Air density also has the direct impact on the propellers. At higher altitudes the density of air is thinner, this affects the performance of propellers, they produce less lifting force. To fly in thinner air some multi-rotor drones need special propeller with another pitch and span.

5. Radio transmitter: this is a channeled transmitter also acts as communicator to the drone. Each channel has specific frequency that is capable of manoeuvring the drone in a certain motion. For effective operation drone requires at least 4 channels. Hail, strong winds, heavy rain, thunderstorms, tornadoes, all these have the capacity to damage this communication system.

6. Battery, Electronics, and Power distribution: The battery is the power source of a drone. It supplies energy in all the electronics in framework through the power distribution cables. Prior Nickel Metal Hybrid or Nickel Cadmium based batteries were used, but now their use has reduced because the use of lithium batteries has increased. They can store a great amount of energy than the Nickel Metal Hybrid and Nickel Cadmium. The rating for a typical battery is 3000 mAh and 4V. The electrical and electronic part is paramount concerning the control and operation of the drone.

However, in the respect to the purpose of the drone, other components can be either included or excluded. The drone may be functional without these parts, though for multitasking purposes it's advised to include them. In hot weather, to work more efficiently propeller draws more power from the battery , so the hot temperature is really challenging and damaging for the battery system. Batteries suffer from the overheating and the risk of permanent damage, because it affects the rate of chemical reaction. Many components such as electronic components, video transmitters, sensors acts up when they get hot. Cold weather also affects the efficiency of battery. Cold temperature reduces the chemical activity in batteries, which causes the power loss faster, in some cases 50% faster. This situation directly affects the flight performance of the system, this cuts the flight time of the system almost by half. In wind conditions drone hast to face more drag, potentially this makes more harder to move forward, to generate more thrust propellers draw more power from the battery and this makes battery life shorter. Many drones have IR sensors, which are sensitive to water accumulation, snow, direct sunlight and any shiny and reflective surfaces. Because of this sensors can miscalculate the distance and in worst case scenario it can lead to crash or loss of drone.

7. Camera: For video footage, cameras are attached to the drones. Cameras with the capability of shooting and storing or sending videos are used. Drone cameras can be sensitive to moisture and they perform bad during this kind of situation. Besides, many drones have IR sensors which are also sensitive to water accumulations, this may cause the sensors to miscalculate distance in the worst case scenario resulting in crash.UAS operation requires some form of first person view (FPV), often in the form of an onboard camera. The distance camera see can be reduced by dense fog ,clouds, or haze . Consequently , UAS may fly into buildings, manned aircraft, power lines , vehicles and many other objects. Flying through clouds can result in condensation on the camera lens. Due to the hot weather , drone pilot loses the video feed when the temperature exceeds 100F and this situation is common.

8. Landing gear: This is a structure made for safe landing of the drone. However, it can be spared since because an experienced pilot is capable of balancing the motors speed for safe landing in emergencies. There are two major types of landing gear, one is fixed gear and the other is retractable landing gear. Sometimes, when you fly your drone in cold temperature there is chance that ice may accumulate on the landing gear, this will result in landing problems.

III. CONCLUSION

Till now many flight events have been studied under different types of weather conditions and it has been noticed that the weather conditions directly affects the aircraft performance whether it is manned or unmanned. In UAS flight, it has noticed that major power consumption occurs during the icing conditions and second highly power consumption occurs during the strong winds. The less power consumption and safe flight occurs during the calm weather. Ice buildup on propellers during the ice conditions led to crash in most flight, strong winds cause the motors to work harder, more power consumption and in most cases it also caused the loss of communication. Most drones are not IP rated, therefore in rain, heavy fog, snow mostly flights were failed to crash because of short circuiting of electronics. Camera doesn't work properly due to sensitivity to moisture and so many drones are with IR sensors which are also sensitive to water accumulation, this led them to miscalculate the distance. During the high altitude propellers have to work harder to generate more thrust. Cold and hot weathers affect the battery life and make the flight time shorter. Strong winds, tornadoes, thunderstorms, heavy rain, cause loss of communication and lack of stability lead to crash. Fog, precipitation, cloud, glaze challenges the visibility factor. Further research is needed to understand the impacts of weather on different kind of UAS. This paper provides the weather conditions and the impact on the UAS.

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