AN OVERVIEW OF USING UNMANNED AERIAL VEHICLE AS AN ALTERNATIVE SOLUTION FOR CLOUD SEEDING PROCESS

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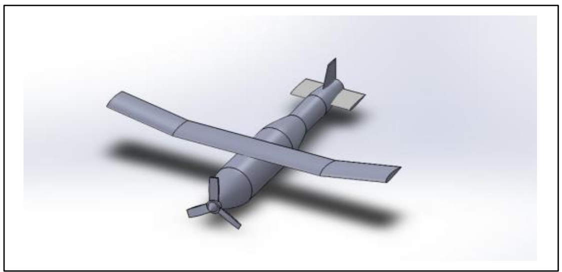
GRAPHICAL ABSTRACT



ABSTRACT

Cloud seeding is a process to modify the clouds to produce rainfall. It is a common practice in some countries that experience El-nino phenomena which come with bad hazes and drought in long duration, such as Malaysia. Generally, cloud seeding process is done by using small aircrafts, which is costly and dangerous to the pilots. Thus, the use of Unmanned Aerial Vehicle (UAV), which is a pilotless aircraft, can be a solution for the implementation of cloud seeding process. This paper presents a brief overview on the cloud seeding process, weather pattern in Malaysia and the minimum specifications of UAV for cloud seeding purpose. It is found that any proposed designs of UAV should have the capability to operate at minimum service ceiling of 2000 m to modify the clouds.

KEYWORDS

UAV; Cloud Seeding; El-nino

INTRODUCTION

Unmanned Aerial Vehicle (UAV), or also known as Drone, is a pilotless aircraft already being used for more than 100 years. It is predicted to be the most important technology regardless of which field it is created for. The main reason of UAV development is to fill the weakness of the conventional aircrafts. Conventional aircrafts are more expensive compared to the UAVs because of the size of aircraft, material used, and technologies inside the aircraft. Flying conventional aircrafts is also more risky than UAVs as they require human as pilot. Hence, by replacing conventional aircrafts with UAVs, it is believed operational cost could be reduced, besides not having to risk pilots. Nowadays, UAVs are used in fields such as agriculture [1], surveillance [2-3], military [4], and etc. Therefore, the possibility to use the UAVs technology in the cloud seeding process during El-nino season is not beyond the capability of engineers.

As reported in [5], Malaysia has experienced El-nino phenomenon more than 12 times since 1951, with some catastrophic incidents occurring in 1982, 1983, 1997 and 1998. It caused a long period of hazes and drought that lead to other problems to Malaysia such as environmental issues, economy and health. Therefore, cloud seeding process has been introduced and now is essential to reduce the effect of El-nino.

Cloud seeding process is a process to modify the clouds to produce rainfall [6-8]. Generally, it is implemented to reduce the effect of long period of hazes and drought caused by the El-nino phenomenon. Cloud seeding involves chemicals concoction process to increase the size of the droplet [6-8]. As reported in the literature, the chemicals that normally used are argentum iodide, dry ice, and table salt [6-7, 9-10]. Argentum iodide and dry ice are the seeding agents which are used to promote rain in regions where temperature is below freezing point, while table salt is used in regions where temperature will not drop to freezing point. As explained in Weather Modification Incorporation, the cloud seeding process can be categorized into two, which are aerial cloud seeding and ground-based cloud seeding [11]. Aerial cloud seeding process is the method of transferring the seeding chemicals to the cloud by using aircraft such as two-seater airplanes or helicopters. Ground-based cloud seeding is the process of dispersing the seeding agent from the ground to the cloud by using ground based generators. The ground-based cloud seeding is more cost-effective but lack in effectiveness compared to aerial cloud seeding [11], which is the reason the aerial cloud seeding process is more favourable in Malaysia.

For the last two decades, aerial cloud seeding process in Malaysia was done by using small aircrafts like Cessna, which needs to be operated for at least three hours and involve cost around RM20, 000 to RM30, 000 for a small scale of area. According to Malaysian Meteorological Department [5], this cost can reach about RM80,000 if the cloud seeding process is operated by the Royal Malaysia Airforce (RMAF) as they use bigger aircrafts in order to cover large area. Besides the expensive cost of operation, the lives of pilots are also in danger as they have to manoeuvre the aircraft in heavy rain, since usually after the cloud seeding process is carried out and depending on the weather, rain will fall very soon and even sometimes with storms [12]. For that reason, the need to use the UAV technology in cloud seeding process is essential to reduce the operational cost and cut the need of a pilot.

The objective of this paper is to provide a brief overview of the important criteria to be taken into consideration for developing UAV for cloud seeding process in Malaysia. Discussion covers the El-nino weather pattern in Malaysia, cloud seeding process and the type of the available UAVs in the open market. Based on overviews, a minimum requirement and basic specification of an UAV for a cloud seeding process are recommended.

El-Nino Weather Pattern In Malaysia

El-nino is a phenomenon due to the weakening of trade wind in Eastern Pacific water that results in the increase of temperature in Western Pacific, as shown in Figure 1 [13]. El-Nino phenomenon can cause serious effects in various aspects, for example, the nature surrounding, world weather, economy, and health [13]. For nature surrounding, the effects of El Nino are very dangerous as the increase in temperature will threaten the life of the marine aquatics, as well as the quality of water resources for agriculture. It could also decrease the quality of river and seawater that automatically will drop the quality of water used for the industry. El-nino also has a tendency to give an abnormal effect in climate such as sun ray, temperature, atmospheric pressure, wind, and also cloud formation.

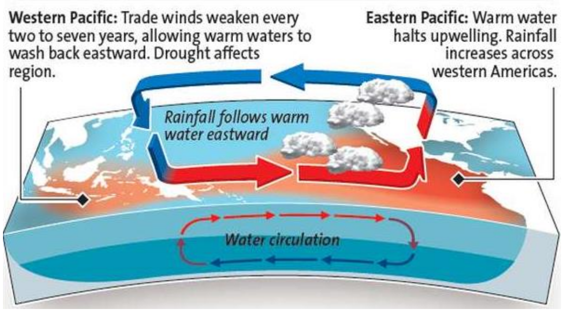


Figure 1: El-nino phenomenon [13]

S.Tashny and T. Michelle [13] also reported that the longest recent El-nino phenomenon experienced by Malaysia was in June 2009, which lasted for about 10 months with a dry spell. During this time, 60% of Klang Valley consumers faced a drier spell than that experienced during the recent water crisis. The El-Nino also affected the Malaysia economy, as some businesses which are sensitive to change of the temperature. For example, in agriculture, some planting seeds are dependent on the temperature of the surrounding. According to the report presented in [13], during this time, the price of crude palm oil increased sharply because the production of crude palm oil was decreasing due to the hot temperature.

Based on these reviews, it shows that cloud seeding process can be very crucial, can be continuously carried out whenever Malaysia experiences the EL-nino phenomenon.

Cloud Seeding Process

According to S.J. Solanki [6], cloud seeding process can be defined as a method to form rain by spreading the seeding agent, for example dry ice and argentum iodide aerosol into cloud to increase the precipitation process of ice molecules. As reported in [14], the cloud seeding idea appeared in 1946 when scientists at General Electric laboratories in Schenectady, New York, accidentally discovered super-cooled ice crystal formation formed from solid carbon dioxide. Then, series of experiments were carried out in laboratory and through atmospheric trials.

In general, the aerial cloud seeding process can be categorized into three methods. The first method is the static cloud seeding process. This process is carried out in regions where the temperature is below the freezing point. Usually, the best seeding agent used in this situation is Argentum Iodide because it can promote the cloud to drop the rain more efficiently [15]. The second method is dynamic cloud seeding [16]. This process is similar in term of seeding agent and the targeted region used in static cloud seeding, but the quantity used is different. The target ice concentration in dynamic cloud concentration is much larger compared to static cloud seeding, and of course the quantity of seeding agent is also more [16].

The last method is hygroscopic cloud seeding. This method is most recommended to be used in Malaysia as it has the capability to produce higher quality rain in a region where the temperature is above zero degree Celsius. The material used in this process is table salt, or calcium chloride. While static and dynamic cloud seeding methods are carried out in regions where the temperature is below freezing point, the hygroscopic cloud seeding is done in regions where the temperature is above freezing point. The seeding agent is sprayed on the base of the cloud to make the ice molecules in the cloud to combine with the salt molecules to generate bigger size of ice molecules. As reported in [6], once the size of ice molecules is big enough, they will drop as rain.

In 2009, China researchers conducted cloud seeding operations using rocket type mechanism as shown in Figure 2 to clear the air from drought [17]. They using iodide to create rain and at the end of 2009, Beijing had its earliest snowfall since 1987 [18]. In the context of research and development of rocket technology in Malaysia, we are still far behind China or other advanced countries. It seems difficult and may need many years ahead for Malaysia to establish rocket technology that could be used for the cloud seeding process.

Figure 2: Cloud seeding process using rocket mechanism [17]

Therefore, at the moment, the only alternative for Malaysia to carry out cloud seeding without risking human life is by developing UAV. The research and development of UAV in Malaysia can be considered well established, with many companies such as Unmanned System Technology (UST) and Sapura Holding having developed their own UAVs technology for military and surveillance purpose.

Besides local companies, intensive researches on UAV have also been carried out at local universities such as Universiti Teknologi Malaysia (UTM) [19-21], Universiti Malaysia Perlis (Unimap) [22-23] and Universiti Sains Malaysia (USM). Therefore, the option to use the UAVs technology for cloud seeding process in Malaysia can be realized.

The cloud seeding process has to be carried out at the altitude of altocumulus and altostratus cloud, at height of around 2000 meter of altitude. For that reason, the minimum specification of the proposed UAV is that it must be able to cruise at a minimum altitude of 2000 meter (6500 ft.). Hence to start the parametric study of UAVs, the aircraft should have a minimum service ceiling of 2000 m.

Unmanned Aerial Vehicle

UAV is defined as an aircraft remotely controlled by human from the ground station [24]. UAV has already existed since World War 1, when the first lighter-than-air balloons were designed to collect information about enemy bases, movements, and many more [25]. Although nowadays the balloons are no longer included in categories of UAV, they are still the first units that fulfilled the role of UAV at that time [25].

According to Wongui [26], UAVs can be classified into five classes, by altitude and endurance. The classes are Low Altitude UAV, Medium Altitude UAV, Medium Altitude Endurance, High Altitude, and High Altitude Endurance (HAE). The Low Altitude UAV can fly at altitude lower than 20,000 ft. Examples of Low Altitude UAVs are Hunter, Aerosonde, Cutrider, and Shadow UAVs.

Medium Altitude UAV can cruise at altitude higher than Low Altitude UAV but limited to 45,000 ft and usually the UAV flies in the troposphere. The Medium Altitude Endurance (MAE) UAV can fly at similar level flight with Medium Altitude UAV but can fly more than 24 hours. Examples of this type of Medium Altitude Endurance are Gnat 750, Predator and Heron UAV [26].

The next class is High Altitude UAV. This type of UAV can fly at altitude higher than 45,000 ft and can fly in the stratosphere region [26]. The example of this type of UAV is Dark Star. The HAE (High Altitude Endurance) UAV ranks in the highest class in categories of altitude and endurance. It can fly at altitude higher than 45,000 ft. Similar to High Altitude UAV, it can also fly in stratosphere but the endurance is more than 24 hours. Examples of this type of UAV are Global Hawk, Theseus, BQM-34, and Altus2 [26].

The classification of UAV can be different from the classes explained before. According to M.d.F Bento [27], UAV can be classified based on flight altitude, endurance, speed, maximum take-off weight, size and mission. The first class of UAV includes micro or mini UAVs. The maximum take-off weight for this class is from 0.1 kg to 30 kg and can fly in duration of one to two hours. The missions this UAV usually involve scouting and surveillance inside buildings [27].

The second class is tactical UAV. The maximum take-off weight for this UAV is between 150 kg to 1500 kg and can fly up to 8000 meter. Besides that, the endurance for this UAV can reach up to 48 hours, while the data link can range up to 500 km. In general, the tactical UAV is assigned to do search and rescue missions, and communications relay [27].

The third class is strategic UAV. The maximum take-off weight for this UAV is between 2,500 kg to 12,500 kg, and can fly at altitude higher than 15,000 meter [27]. Examples of this type of UAV are Global Hawk, Raptor, and Pathfinder Plus. The last class is the Special Task UAVs. Examples of this UAV are MALI, Pegasus, and MAC-1. This type of UAV usually has anti-radar, anti-ship, and anti-infrastructure missions [27].

As summary, there are already many types of UAV available in the market. However, the cloud seeding purpose seems to favour the low altitude and low velocity type of UAV, as it only has to fly and operate at minimum service ceiling of 2000 m, which indirectly could reduce the design cost.

Proposition of Initial Configuration

The initial specification and configuration for the UAV suitable for cloud seeding process can be identified through parametric study on several available UAVs, referred from open literature based on the minimum specification explained previously. This is done just to have an idea of the minimum specification and configuration of UAV to be able to fly and operate at minimum service ceiling of 2000 m.

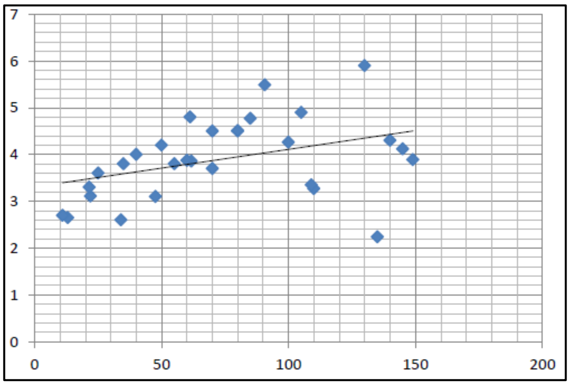
Parametric Study of UAV

This parametric study was done by referring to the available UAVs in the market which have service ceiling above 2000 m. From the data collection, the parametric analysis was done by plotting various graphs such as Maximum Take-Off Weight (MTOW) versus Endurance, MTOW versus Payload Weight, MTOW versus Wing Span, MTOW versus Cruise Speed, and etc. The MTOW of UAV was estimated to be around 50 kg, based on the weight of available UAVs which have service ceiling between 1500-2500 m. Thus, all the needed data were predictable based on this weight.

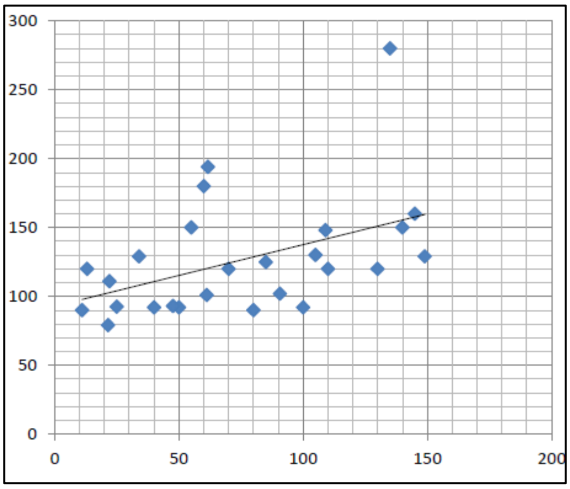
From the plotted graphs, data such as the wingspan of the aircraft (Figure 3a), gross weight, payload, cruising speed (Figure 3b) and power can be estimated, as can be seen in Figure 3. All the data obtained can simplify the design process, but it should be noted that the data are just the estimation. Although the data will not give exact values, it can lead the design process toward success. By knowing the general specification of the UAV, other parameters can be calculated by using several approaches. Table 1 presents the proposed minimum specification and configuration of UAV, as referred from parametric study, to operate at minimum service ceiling of 2000 m to modify the clouds.

Conclusion

From this study, it can be concluded that Malaysia often experience El-nino phenomenon which cause long duration of drought season, which then lead to other problems. Moreover, the current limitations of cloud seeding process in Malaysia could cause the effects of El-nino getting worse. Therefore, the recommendation of using an UAV as a new solution for cloud seeding process to promote rain during drought season, especially by El-nino phenomenon, has become necessary to be considered to overcome the current limitations of cloud seeding process in Malaysia. Hence, the elementary configurations and specifications of UAV which are suitable for a cloud seeding process have been proposed in this paper, but still require further studies and development.



(a) Wing span (m) versus MTOW (kg)



(b) Cruising speed (ft/s) vs MTOW (kg)

Figure 3: Example of parametric study using data from available UAVs

Table 1: Initial estimation of configuration for proposed UAV

Aircraft Name :	**Awan 1**
<u>Weight</u>	
Gross weight (MTOW):	50 kg (estimation)
Fuel weight:	8 kg (estimation)
Payload:	12.5 kg (estimation)
Empty weight:	29.5 kg (estimation)
<u>Wing</u>	
Wing span:	3.8 m
Wing area:	1.52 m^2
Chord length:	0.4 m
Aspect ratio:	9.5
Wing loading:	32.895 kg/m^2

Fuselage	3.5 m
Overall length:	0.5 m
Width:	0.5 m
Height:	
Horizontal tail	
span	1.2 m
chord	0.4 m
Aspect ratio:	3 m
Area:	0.48 m^2
Vertical tail	
Span:	0.3 m
chord:	0.2 m (tip)
	0.3 m (root)
Area:	0.12 m^2

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REFERENCES

[1] J. Gago, C. Douthe, R.E. Coopman, P.P. Gallego, M. Ribas-Carbo, J. Flexas, J. Escalona, H. Medrano. 2015. UAVs challenge to assess water stress for sustainable agriculture. Agricultural Water Management 153:9-19

[2] A. A. Doshi , A. J. Postula, A. Fletcher, S. P.N. Singh.2015. Development of micro-UAV with integrated motion planning for open-cut mining surveillance. Microprocessors and Microsystems 39:829–835

[3] X. Cheng, Q. Ge, S. Xie, G. Tang, H.Li. 2015. UAV gesture interaction design for volumetric surveillance. Procedia Manufacturing 3: 6639 – 6643

[4] M. Moorkamp, J.L Wybo, E.H. Kramer. 2016. Pioneering with UAVs at the battlefield: The influence of organizational design on self-organization and the emergence of safety. Safety Science 88:251–260

[5] Malaysian Meteorological Department. 2015. El-Nino/ La Nina Retrieved 03 April 2015 from http://www.met.gov.my/web/metmalaysia/education/weather/weatherphenomena/elninolanina?p_p_id=56

[6] J. Simpson, V. Wiggert T.R. Mee. 1968. Models of seeding experiments on supercooled and warm cumulus clouds. Bull. Am. Meteorol. Soc. 34:160.

[7] X.L. Guo, G.G. Zheng, D.Z Jin. 2006. A numerical comparison study of cloud seeding by silver iodide and liquid carbon dioxide. Atmos. Res. 79:183–226.

[8] R.R. Rogers, M.K. Yau. 1989. Formation and growth of ice crystals. A Short Course in Cloud Physics, International Series in Natural Philosophy. Butterworth-Heinemann, Burlington, pp. 150–169.

[9] R.T Bruintjes. 1999. A review of cloud seeding experiments to enhance precipitation and some new prospects. Bull. Am. Meteorol. Soc. 80:805–820

[10] A. Zipori, D. Rosenfeld, J. Shpund, D. M. Steinberg, Y. Erel. 2012. Targeting and impacts of AgI cloud seeding based on rain chemical composition and cloud top phase characterizatio. Atmospheric Research 114-115:119–130

[11] Weather Modification, Inc. 2005. Introduction to Seeding Agent. Retrieved 05 April 2015 from http://www.weathermodification.com/cloud-seeding.php

[12] Bernama. 2014. Cloud-seeding operation continues, focus on the south. Retrieved 28 March 2015 from http://www.themalaysianinsider.com/malaysia/article/cloud-seeding-operation-continues-focus-on-the-south-bernama

[13] S.Tashny and T. Michelle. 2014. Prolonged dry spell looms over Malaysia. Retrieved 20 March 2015 from http://www.thestar.com.my/news/nation/2014/05/12/prolonged-dry-spell-looms-over-msia-severe-el-nino-effects-predicted-to-hit-in-second-half-of-the/

[14] Donna. 2012. Rainmaker: A Brief Explanation of Cloud Seeding. Retrieved from 21 March 2015 from http://www.brighthub.com/environment/science-environmental/articles/120525.aspx

[15] SOAR. 2005. Glaciogenic cloud seeding. Retrieved 15 April 2015 from http://www.just-clouds.com/glaciogenic_cloud_seeding.asp

[16] Cotton. 1997. Weather Modification by Cloud Seeding. Retrieved from 15 April 2015 from http://rams.atmos.colostate.edu/gkss.html

[17] A. Hafiz. 2014. Pembenihan awan 'penyelamat' musim kering. Retrieved 16 May 2016 from http://www.kosmo.com.my/kosmo/content.asp?y=2014&dt=0226&pub=Kosmo&sec=Infiniti&pg=in_02.htm#ixzz3FclIZnD3

[18] T. Branigan. 2009. Nature get a helping hand as snow blankets Beijing. Retrieved 05 March 2015 from http://www.theguardian.com/world/2009/nov/02/china-snow-beijing.

[19] Hafizan. 2015. UTM launched UAV CAMAR 1 prototype. UTM. Retrieved 16 May 2016 from http://www.news.utm.my/2015/01/utm-launched-uav-camar-1-prototype/

[20] The Star Online. 2015. UTM achieves unmanned aircraft milestones. Retrieved 16 May 2016 from http://www.thestar.com.my/metro/community/2015/02/21/utm-achieves-unmanned-aircraft-milestone/

[21] Utusan Online. 2015. UTM pamer kehebatan prototaip UAV. Retrieved 16 May 2016 from http://www.utusan.com.my/berita/nasional/utm-pamer-kehebatan-prototaip-uav-1.48419

[22] Bernama. 2013. Unimap to develop UAV technology with German company. Retrieved 15 May 2016 from web10.bernama.com/education/index.php?sid=news_content&id=988291

[23] Utusan Online. 2011. Unimap terokai teknologi UAV. Retrieved 15 May 2016 from http://ww1.utusan.com.my/utusan/info.asp?y=2011&dt=1214&pub=Utusan_Malaysia&sec=Kampus&pg=ka_03.htm

[24] C. Cole and J. Wright. 2010. What are drones? Retrieved 15 March 2015 from http://dronewars.net/aboutdrone/

[25] J.D. Blom. 2009. Unmanned Aerial systems: A historical perspective. Combat Studies Institute Press, US Army Combined Arms Center Fort Leavenworth, Kansas.

[26] B.B Wongui. 2010. Morphing Unmanned Aerial Vehicles. AALTO University, Faculty of Engineering and Architecture. Master Thesis

[27] M.d.F Bento. 2008. Unmanned aerial vehicles: An overview. Working papers Inside GNSS. www.insidegnss.com Janfeb08-wp pp: 54-61