Development And Certification Flight Test Of Unmanned Aerial Vehicle (UAV) Pesawat Terbang Tanpa Awak (PTTA) Wulung

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Abstract: Development and certification of flight test for UAV is new challenge in Indonesian aviation industry.This paper explains about development and certification of flight test program of Unmanned Aerial Vehicle (UAV) called PTTA Wulung that was conducted by PT Dirgantara Indonesia (Indonesian Aerospace).The final goal of flight test is to fulfill regulation that is required by Indonesian Military Airworhiness Authority (IMAA). Flight test program/campaign consists of aircraft system and flight characteristic evaluation. Flight characteristic evaluation included take off and landing performance, climb stability, stall and glide. Aircraft system test consist of autopilot, electric, flight control, communication, propulsion and mission system evaluation. In this paper also explain about data aqusition and data processing to support flight test and evaluation.
Key Words: Flight Test, Development, Certification, Unmanned Aerial Vehicle, Data Analysis

Nomenclature

AC	Advisory Circular
CASR	Civil Aviation Safety Regulation
CD	Coefficient Drag
CL	Coefficient Lift
CG	Center of Gravity
FAA	Federal Aviation Administration
GCS	Ground Control Station
Hz	Hertz
IMAA	Indonesia Military Airworthiness Authority
PT DI	PT Dirgantara Indonesia
PTTA	Pesawat Terbang Tanpa Awak
TSRB	Technical Safety Review Board
UAV	Unmanned Aerial Vehicle
PCC	Picollo Command Center

1. Introduction

The goal of flight test program is to study aircraft characteristic comprehensively not only flight performance and stability but also to meet design requirement. Flight test is needed to prove that combination between human and machine is able to reach desired performance[1)]. By performed, several flight manuever and system evaluation during flight and ground, the aircraft performance can be evaluated based on design requirement. Flight test activities consist of aircraft performance test, stability, basic system and support system or mission system such as camera, radar and other sensor.
Flight test is a part of product development and certification process. This process usually to be considered in the end of design process or when the aircraft was fabricated and ready for flight. There is several classification of flight test such as development and certification flight test, production flight test and after maintenance flight[1)].
Unmanned Aerial Vehicle (UAV) or drone was known and very popular not only in aviation industry but also in others industry. Several aplication the example aerial photograph, aerial survey and mapping were applied both civil and military application. The development of UAV aplication is increasing rapidly in parallel with development of their’s support system such as control, computer, electronic and communication system. In the future, UAV application will be more variative. Based on reseach publication released by accenture in 2014, UAV application is clasified baesd on 2 main aspect. The first is complexity and the other is viability. The two aspect was illustrated at picture below.

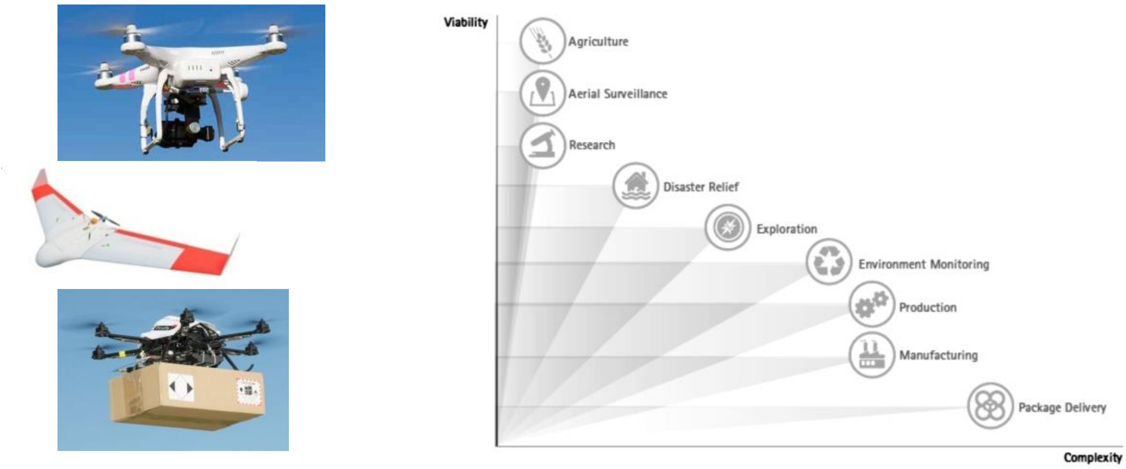

Fig 1.1. Ilustration graph between complexity and viability of UAVapplication in several industry[2)]

The Graph above showed that UAV application in agriculture, aerial survey and reseach is more complex and have a better viability than application in disaster relief, exploration and environment monitoring[2)]. The highest complexity in UAV aplication based on graph were package delivery and manufacturing. The example of company that already used UAV was British Petroleum. They used UAV to inspect piping installation in Alaska[3)].

Increasing demand of UAV application makes safety have to be considered. To ensure safety and security not only for aircraft but also for environment, UAV have to be certified from airwothiness authority. The problem in UAV certification in Indonesia is regulation, nowdays there is no specific regulation for UAV design. Ministry of Transportation or Kementrian Perhubungan have released regulation for UAV operation but it is not included certification for product design. The problem makes Wulung certification process used CASR 23 with tailoring or modification as basic certification. For additonal information, Federal Aviation Administraion (FAA) have released and rectified regulation for UAV operation and known as small UAS rule (part 107) and it will applied effectively in August 2016.

CASR 23 is regulation for design normal category, acrobatic and commuter aircraft, with weight and passenger limitation. This regulation basicly is not for UAV, in order to comply with the regulation, several part from CASR 23 was adopted and modified for basic certification PTTA Wulung. Statement in CASR that have possibility to be applied for UAV was proposed in certification test plan. The diffrences of complexity betwen UAV and manned aircarft affected in flight test program. Flight test program was design as simple as possible. Several part of CASR 23 that can be applied in UAV convert to flight test requirement. Flight test requirement included whole system of the aircraft and then convert to flight test technique and flight test procedure for execution. Flight test technique and procedure that used in this program refer to FAA document AC-23-8C. AC-23-8C document is flight test guide document for certification aircraft category FAR 23 (similar with CASR 23)

Certification model for UAV is the first time for PT DI. Previously PT DI was familiar with certification for manned aircarft to comply CASR 25. With limited experiences in UAV, flight test program succed to finished test item that was planned before. Hopefully in the future, PTTA wulung flight test program could be become role model for UAV certifiation in Indonesia. Flight test technic and procedure during this test should be develop and evaluate effectively to give better result.

2. Methodology

The method showed below was general process that have been done to get certification design for prototype aircraft (Type Certification)

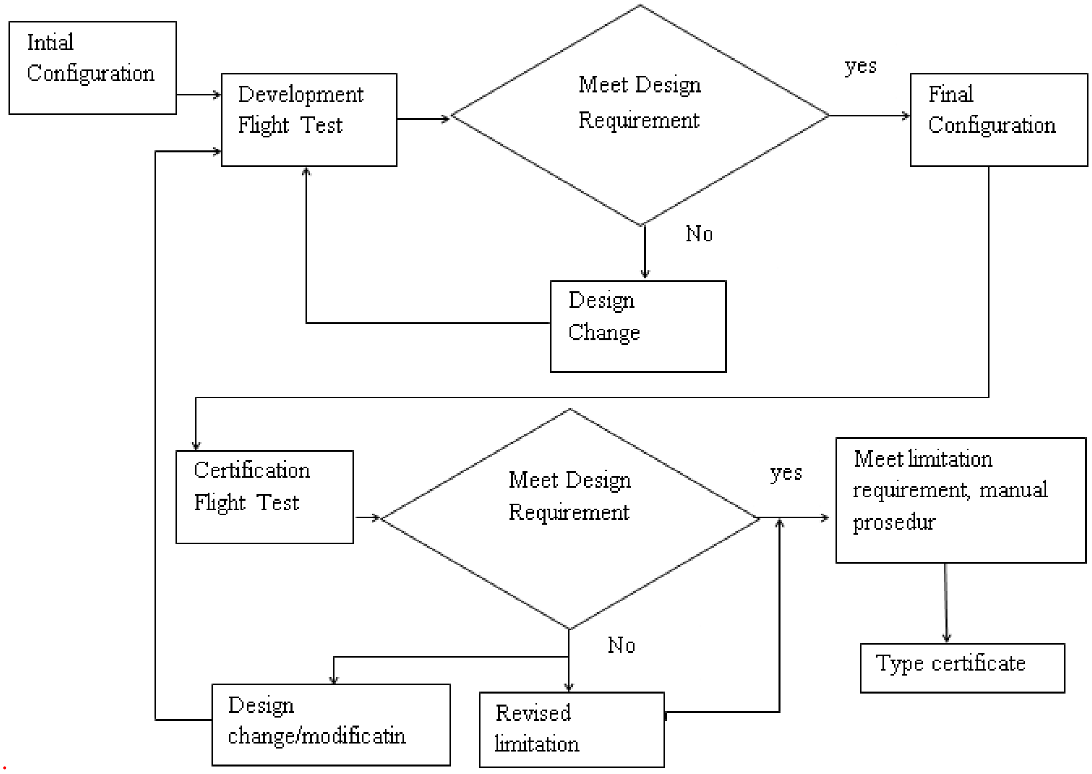

Fig. 2.1. Several step related to flight test activitiy to get type certificate

Detail process for flight test execution and guidance refer to standard operational procedure of flight test center PT Dirgantara Indonesia[4)]

3. Result And Discussion

3.1. PTTA Wulung Dimension and Specification

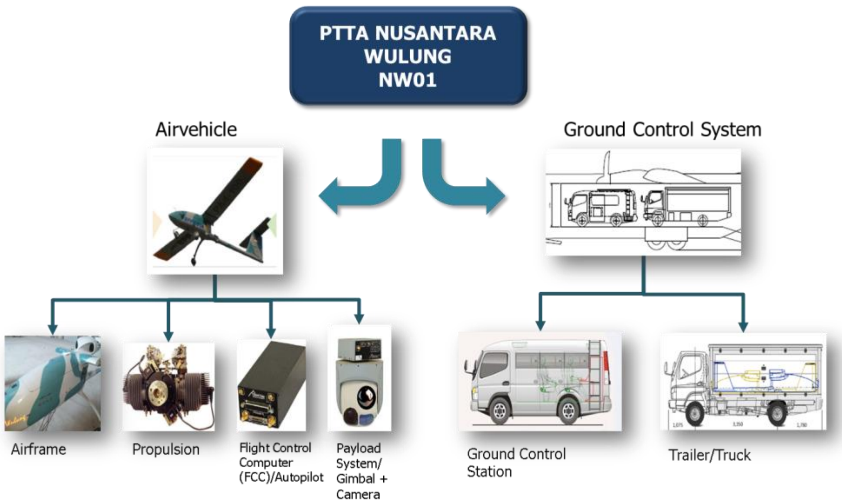

Fig. 3.1.1. Product Definition of Pesawat Terbang Tanpa Awak (PTTA) Wulung[5)]

PTTA Wulung product divided into air vehicle and ground control system. Ground control system consist of ground conrol station (GCS) and transporter. Ground control station (GCS) is mobile control room to monitor aircraft movement and mission system. GCS is able to giving a command to the aircraft when autopilot system was engaged. Ground control station (GCS) equipped with VHF omnidirectional annena for short range communication and parabolic antena for tracking and long range communication. Tranporter is special vehicle that was design to tranport PTTA Wulung with maximum capacity 3 aircraft. Aircraft specification and dimension can be seen below:

Overall Length : 4.42 m
Height : 1.48 m
Fuselage Width : 0.40 m
Wing Span : 6.34 m
Wheel Base : 1.44 m
Wheel Track : 1.60 m

Maximum Take Off Weight : 125 Kg
Maxsimum Empty Weight : 105 Kg
Maksimum Landing Weight : 125 Kg
Maksimum Payload : 32 kg

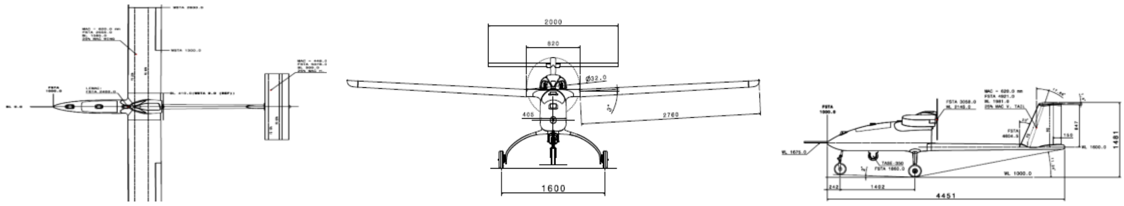

Fig. 3.1.2. Three view drawing PTTA Wulung

3.2. Flight Test Preparation and Execution

Prototype aircraft have characteristc that haven't been explored before. It make safety and security become the most important aspect. Eventhough UAV have lower risk than manned aircraft but aircraft and personel safety is a priority in every flight. Safety priority was implemented in test sequences and test execution. The test was conducted step by step from lower risk to the most dangerous test such as stall. Aircraft readiness and personel is also important for flight test program because of limited resources. Flight test program have to be planned and well managed. Aircraft condition ideally have to be in best condition before flight.

Preparation started since design process and the workload increased when the aircraft started to be manufactured in 2014. Preparation of flight test planning document was important when aircraft system and drawing was ready to be manufactured. Flight test plan is technical document released by flight test engineer departement that consist of test subject and test requirement from completed system such as aerodynamic, performance and structure etc. Each departement in design office or specialist proposed test requirement in order to evaluate their's design. Flight test plan also included technical guidance to conduct flight test such as test location, flight test procedure, flight test technic, infrastucture, safety consideration and schedule. Flight test plan was prepared by flight test engineer that would be a conductor during test execution.

Flight test can be executed if whole system was working properly and calibrated in ground. To ensure that point, there was some laboratorium test and aircraft testing in ground. The test was included in ground test phase. The test that executed during ground test phase such as pitot static calibration, flight control calibration, propulsion, electrical, mission system and autopilot. Ground test for autopilot system evaluated with software and hardware simulation (hardware in the loop simulation) to ensure there was no system anomali during flight. Software and hardware autopilot simulation was important because it isrelated to flight control system and engine. If autopilot system failed, the aircraft would be uncontrolled.

In the end of flight test preparation, there was Test Safety Review Board (TSRB) forum. The goal of this forum was to evaluate flight test preparation focusing in safety aspect. TSRB forum invited indepedent reviewer who was not involved directly to PTTA Wulung program. The output from this forum were recomendation and action item. Recomendation and action item have to be closed and solved before first flight.

Flight test exection divided into: preflight briefing, execution and post flight briefing. Preflight briefing was needed in order to coordinate to all team member and explained about the test itseft. Preflight briefing informed and communicated about aircraft readiness, wheather condition, slot and what test that would be executed (test sequence). Preparation such as weight and CG configuration, fuel, and aircraft defect also would be discused. Test sequence explained by flight test engineer one by one before engine start until aircraft landed and engine shut down.

Flight test execution lead by mission commander who ensure safety during flight. Each test point guided and evaluated by flight test engineer. In this flight test, Misison commander was standing closed to pilot meanwhile in the manned aircraft, misison commander usually monitor from control room. Mission commander have authority to stop the test, if the condition is unsafety to continue the test. Flight test engineer responsibility to ensure flight test execution match with test planning and giving the high quality data, aircraft respond, system performance. Flight test engineer may request to repeat the test if the result was not as expected but additional test beyond test sequences was not allowed[4)]. Flight test exection needs intensive communication and coordination to all team member.

3.3 Flight Test Result and Milestones

Flight test duration of PTTA Wulung for development and certification was around one year, first flight on November 2014 in Batujajar with airborne time for 9 minutes. Mostly the test location were in Nusawiru airport and Batujajar. Development and certification flight test completed 9.98 block hours using 3 aircraft with registration KX-0001, KX-0002 and KX-0003. Flight test program was planned for 13 hours flight (9 hours for development and 4 hour for certification)[6)] Flight test for serial production were held in Wiriadinata airbase, Tasikmalaya and Nusawiru airport.

Tabel 3.3.1. Total flight hours and number of flight each aircraft for development and certification flight test program[7)]

Aircraft Registration	Number of Flight	Flight Hours (block hours)
KX-0001	4	1.25
KX-0002	4	0.90
KX-0003	13	7.83
Total flight numberand flight hours	21	9.98

Flight test program divided into 2 part: aircraft system and flight physic. Flight physic evaluation consist of take off and landing performance, climb, stall speed, stability and gliding. Aircraft system evaluation included propulsion, autopilot, mission system and communication system. The detail of test during development and certification flight test program was:

Flight System
- Propulsion Test
- Flight Control
- Electrical system
- Autopilot
- Mission system
- Transponder

Flight Physics

- Take off distance
- Climb performance
- Glide
- Landing distance
- Drag polar (cruise performance)
- Long range test (communication system)
- High Altitude
- Longitudinal control
- Lateral dan directional control
- Rate of roll
- Static longitudinal stability—cruise
- Static lateral directional stability—cruise
- Dynamic longitudinal stability –short period
- Dynamic lateral directional stability—dutch roll
- Stall speed determination

Flight test sequences executed step by step carefully, started with lower risk test to the most dangerous test. Flight configuration such as center of gravity (CG) set to fulfill test requirement. Several flight physics test didn't need mission system or FLIR camera in order to minimized risk. For documentation need, action camera was installed in RH wing or above horizontal stabilizer. Action camera installation also considered CG location.

During initial phase of flight test, there was several problem related to aircraft system such as landing gear, brake system and propeller. Landing gear problem influenced ground steering capabilty. To solve this problem, modification was made and implemented for the next production aircraft. Milestone and achievement during flight test was :

Stall speed : 42 Knot
Rate of Climb : 300-400 feet per second
Take off dan landing distante : 300-500 m
Maximum altitude during test : 5500 ft
Cruise Speed during test : 45-55 knot
Maximum Range during test : 20 Km
Autopilot : Multiple waypoint and single waypoint
Gliding (rate of descent) : 500-800 feet per second
Maximum flight hoursduring test : 1 hour 10 minute
Maximum Roll rateduring test : 22 degree/second

3.4 Data acqusition and Processing

Flight physic test need data analysis to evaluate and calculate aircraft stability and performance. Autopilot software (Picollo II) provided datalog featured with txt and tel format. Flight data will automatically saved to the datalog folder if autopilot hardware at the aircraft turned off. Data with "tel format" can be rewind in other computer which is installed PCC (Picollo Command Center) software.

Picollo II provided 200 parameter from aircraft altitude parameter to electical and fuel system. From 200 parameter only 40 parameter used for data analysis. Sampling rate data can be set from 1 Hz to 25 Hz. Most of PTTA Wulung data acquisition used 5 Hz sampling rate data. Flight test data was analized using spreadsheet software and the result displayed in time histories graph. The next process, data sent to related departement to be used or to be analized further. The data also used create aircraft flight manual. The Fig. 3.4.1. below shows the example of time histories graph from flight test data.

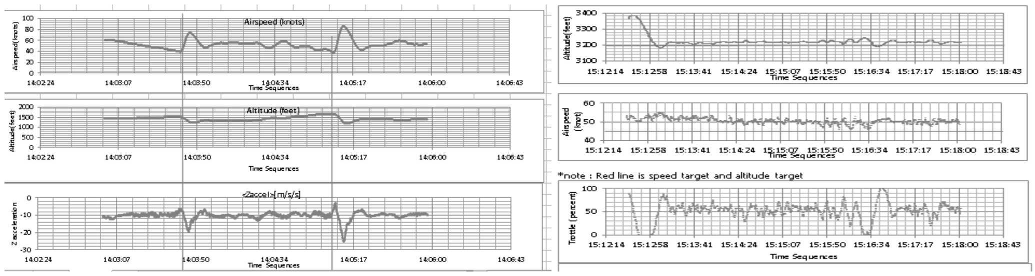

Fig. 3.4.1. The example of time histories graph from flight test data

Fig. 3.4.1 at the right side showed data during stall speed determination test. It was represented airspeed, altitude and roll angle during stall and recover. left side graph showed aircraft parameter during autopilot test, it showed autopilot performance to maintain altitude and airspeed.

Flight data was recorded since Picollo hardware and software in aircraft and ground control station activated. The data then separated or eliminated into specific test segment based on test log. The detail analysis to proces the data was implemented after data reduction. The method to analyzed the data was spesific method based on test technique, the example cruise perormance calculated by Brequet formula and take off landing performance evaluated using Inersial Navigation System (INS) method. Data resources came from several test repetition but the best data to be considered for the best result. Step and method to process the the data explained below

1. Download data dari Groundstation Control System (GCS)
2. Create graph from flight parameter as time function (time histories)
3. Data elimination or reduction based on test log or flight test engineer note
4. Display graph with parameter needed
5. Calculated data from dislpayed parameter using speciifc method or formula
6. Analyzed calculation and compared with requirement or analytical model

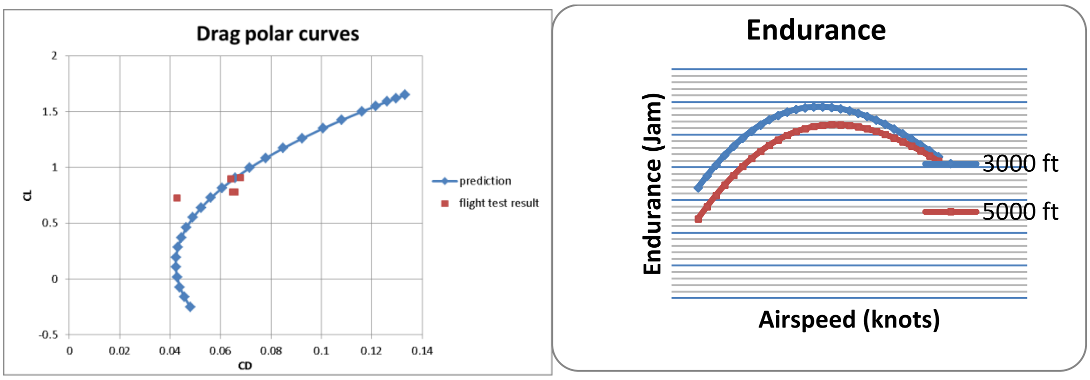

Fig. 3.4.2. The example result from data calculation and data processing

Fig. 3.4.2 was cruise performance evaluation from flight test data. Drag polar curved showed lift (CL) and drag (CD) coefficient during cruise[8]. Drag polar data and then used to calculate endurance and other performance such as specific range.

Data analysis and report submited to the authority (Indonesian Military Airworthiness Authority) for review process. Flight test can be repeated if there is request from authority. After document review and conformity process was completed, autority released type certificate. Type certificate is basic certificate for specific configuration based on technical drawing or technical document from desgin office. The next step in order to send the aircraft to the market, aircraft have to be manufactured with standard quality and well managed production method.Aircraft manufacturer need production certificate to this process included production flight test.

3.5. Obstacles during Flight Test

There was several obstacles during test execution especially technical issues such as aircraft readiness, wheather condition and slot time. Aircraft readiness was important issues during test execution. Prototype aircraft didn't have manual document to perform troubleshooting and estimate spare component. In Some cases, aircrafi readinees problem solved by using component from other aircraft. Weather condition affected to flight test program. Ideally, flight test was executed in the morning to minimized wind disturbance. In the afternoon or evening, wind speed relatively high. Wind condition could be become trouble for pilot during take off and landing.
The next obstacle was related to flight test technique and procedure. Limited experiences in UAV flight test made most of test procedured adopted from manned aircraft. Flight test technique and proceudure of manned aircraft can't be fully implemented in UAV. One of the problem was pilot position. it made the aircraft can't be trim for long time. Trim conditon was hard to maintain because visual limitation of pilot to the aircraft. This problem was affected during stabiliy and performance test which need trim condition (constant speed and altitude) before test execution. Another obstacles wasthe primary information such as airspeed, altitude, bank angle, pitch and heading were not infrom directly to the pilot. Pilot got aircraft information from radio that was transmitted from ground control station.If the aircraft flew to high or to far, pilot have difficulty to estimate aircraft orientation

4. Conclusion

Development and certification flight test of PTTA Wulung executed based on test planing. Flight test program completed 9.98 block hours from planning 13 hours (9 hours development and 3 hours certification). Flight test campaign duration was around 1 years with 21 total flight and using 3 aircraft. The result of test either flight pyhsic or aircraft system were satisfied and meet Indonesian Military Airworhiness Authority (IMAA) requirement.
Most of the test based on the test plan was succesfully conducted. Several test was modified,. Modification of flight test procedure was considering actual condition such as pilot obstacle, system and aircraft limitation. Data that was analyzed was collected from several repetition and flight condtion which was giving the best result. In conclusion this development and certification flight test could be implemented in other UAV development. Several method and flight test technique that have been implemented have to be develop and there is possibility to develop new method which is costumized for UAV. The method that was impelemted in this program should be compared with existing method from other UAV manufacturer.

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