DRONE OPERATIONS

&

MANAGEMENT PROFESSIONAL

(DOMP)

CONTENTS

1. WHAT IS A PROJECT

We can define a project as '*a scheme within a certain time frame that is intended to fulfil a definite purpose. A project needs careful planning and concentrated effort by a group of people.*'

Let's break this definition down into its different parts.

A project:

is a scheme: it is a unique and clear plan or enterprise

fulfils a definite purpose: a project is a designed to achieve particular set of aims that are specified

needs careful planning: organized preparation for the project in terms of resources such as money and personnel is vital

is undertaken by group of people: a project is a carried out not by an individual but by a set of individuals

needs concentrated effort: completing a project is hard work and requires constant efforts

2. STARTING A PROJECT

What steps do you need to consider as your start to a project?

- Clarify the idea: Refine precisely what you are trying to do.
- Define your aims: It is essential to be clear about what your objectives are.
- Make sure you have the agreement of senior management towards your aims, objectives, outcomes and all the required resources. This may involve carrying out a feasibility study to make sure that the project is sound.
- Assess risks: It is important to identify and manage risks so that any threats of possible risks are minimized. Uncertain events could prevent your project from being carried out successfully.

  For example:

  i. Is the authority of the project leader clear?
  ii. Is the schedule realistic?
  iii. Have sufficient financial resources been made available?
- Make a business case. If the project is feasible, you should state the expected benefits that the project would bring against the likely cost. Senior management can then consider the business case and approve the project.

One good way of helping you start thinking about a project is to draw a pattern diagram (also known as a 'mind map' or 'spider diagram'). Take a blank piece of paper. Arrange it in landscape position and write the name of the project in the middle. Write a word or few words, but not a whole sentence. You may find it helpful to work in pencil, as you can rub out what you write if necessary.

Now write around your central word(s) the different key aspects of the project that come to your mind. You do not need to list ideas in order of importance; simply write them down. To begin with, you do not need to join the ideas up with lines linking connected items.

If you get stuck at any point, ask yourself the question…why, how, what, who, when, and how much. These may well set you thinking.

How easy the task is: it doesn't feel like work! The ideas and concepts seem to flow naturally and spontaneously you'll know how valuable that piece of paper is. I have captured all (or at least some or many) of the key points. I don't want to lose that piece of paper!

3. ASSEMBLING A PROJECT TEAM

At an early stage in the project-planning process, you need to gather together the following people in a project team. The purpose of this is to ensure that the preparation is undertaken well. The people or organizations with a strong interest in the outcome of a project are called its **stakeholders**.

Circulate a list of everyone involved in the project team to the stakeholders, showing their names, job title, contact details [phone, mobile, email, fax].

(i) **Project sponsor**: A senior member of staff, such as a director of a company or an organization, who can prove that the costs and benefits of the project are worthwhile. He or she will also need to convince other colleagues in the company or provide the time and resources being spent on it. He or she will have the required money and other resources.

(ii) **Project manager**: The person who reports to the project sponsor and is responsible for implementing the project. The project sponsor should give the project manager the responsibility and authority to carry out the project.

(iii) **Team members**: The project manager, in liaison with the project sponsor, can delegate tasks to the team members. The project manager delegates to skilled team members whom he or she can trust to get on with the tasks delegated. If they are less experienced, the project manager will need to train, monitor and supervise the colleagues more.

(iv) **Users** [or customers]: The people who will use the end result of the project. It is important not merely to consult such people but to understand their needs and involve them in the project so that they feel a valued part of the decision-making process.

(v) **Suppliers**: The people who carry out certain tasks in the project. Such colleagues may be within or outside your company or organization. Examples are

colleagues working in departments that deal with sales, accounts or computers. Suppliers will ensure that the requirements of the project are met, given the time and financial resources agreed.

4. ORGANIZING YOUR TEAM

If it's a large project, you will probably split the organizing of the team and its stakeholders into two different groups:

(i) The steering committee (or project board)

This comprises the project sponsor, the project manager and representatives of users and representatives of suppliers. The role of the steering committee is to ensure that the business case is feasible, that the project's end result is usable and that it is achievable, given the required supplies.

(ii) The project team(s)

This comprises the project manager and key colleagues who will actually carry out the project's tasks, or – if the project team is large – representative of such colleagues. However you organize your team, it is important to clarify and agree the roles, responsibilities and authority of each person.

5. CLARIFYING THE PROJECT

Ones you have gathered all the key members of your project team, you will need to hold an initial meeting to discuss the broad parameters of the project. The purpose here is not to go into detail [which will follow later], but to gather information around key areas.

Ideally, the project sponsor would chair this initial meeting, and would begin the meeting by clarifying the reasons why such a project was significant at that time.

Examples of matters to be discussed at this initial meeting could include the following. [Note that it is important to record the point discussed and agreed.

(i) Context: What needs is the project intended to satisfy? How was the present situation developed? How does the project align with the company's or organization's overall strategy?

(ii) Schedule: What is the project's timescale? When can it begin? By when does it need to be completed? Is the end date critical? For example, if the project is to complete the manufacture of toys for Christmas, they would need to be available for delivery in plenty of time for December.

(iii) Strategy: Have the needs been identified? What different approaches have been suggested to satisfy those needs? What precisely does the customer want to be delivered?

(iv) Resources: Has a budget for the project been established? Is there sufficient time to deliver the project? How many members of staff need to be involved? What outside suppliers need to be involved? Have the benefits been analysed against the costs? Where will the project team be located?

(v) Limitations: Having defined what you want the project to do, what do you not want it to do? For example, if you are updating the financial software of a

company, you need to ask to what extent you want to change, if you want to change your existing book keeping and accounting methods. Further, there are legal, security or health and safety requirements that you need to comply with? What risks (uncertain events) can you identify?

The aim here is to produce a document that shows:

1. The context of the project i.e. its background
2. The aim of the project
3. The needs of the customer
4. A statement that your project will meet the customer's needs
5. The benefits that the project will bring
6. The cost of the project and return on investment
7. The timescale of the project [start, end and the key intermediate points]
8. The human resources needed
9. The potential risks of the project.

6. SMART GOALS

Your statements of what you are to deliver and the resulting benefits should be SMART, as defined in the following table:

S **Specific**: not vague but defined precisely

M **Measurable**: quantifiable so that you can check your progress objectively

A **Agreed**: to be approved by all involved in the project, that is, the business, users and suppliers.

R **Realistic**: achievable and within reach of the team

T **Timed**: showing stated dates for start, intermediate stages and for completion

7. DEFINING A SCOPE OF WORK

So far, we have discussed:

- What is a project?
- Starting a project
- Assembling a project team
- Clarifying the project.

(i). It is now time to add further detail to the thinking in order to produce a scope of work and again, approval for the project. Such a scope of work builds on the information that you have already obtained. A statement of scope of work is also known by other names in companies or organizations. Such names include ‘terms of reference ‘or ‘project brief’. If you are in doubt as to the precise contents of the scope of work or its equivalent, check with a senior colleague in your company or organization to find out your policy on such matters.

(ii) It provides a definite standard against which progress can be measured. The scope of work will be included in the statement mentioned below:

a) **The project’s objectives, background, scope and limits** that is, what the project is and is not going to do
b) **The customers’ expectations**, specifying in detail what the project will deliver (for example, the exact type and number of products). It will also include reference to any relevant legal standards that will be complied with
c) **The budget** (showing the financial resources needed)
d) **A list of other physical resources** (such as new offices, computers)
e) **Criteria for acceptance** (for example, if I am writing a book, the publisher will make payment to me only when they consider the work I deliver to be of an acceptable standard)
f) A list of **the main colleagues** on the project team
g) **Delivery dates** for the products
h) **Assumptions** made about the project; **risks** that could have an effect on the implementation of the project.

i) A contract will include such a scope of work and specify payments and when payment is to be made (for example, linked to the delivery of certain products) and other relevant facts (such as patents on products or rights of ownership).

j) You are in a position to present your case. You have the result of a feasibility study and a scope of work. The project sponsor will present these at a senior level in order to obtain approval for the project to go ahead.

8. THE QUALITIES OF A PROJECT MANAGER

A project manager i.e. the person landing a project – who implements it through to achieving its desired purpose should be:

- **skilled in leadership**: clear vision and good communication skills are essential
- **a good team leader**: respecting others and focusing on people's strengths
- **a good with people**: able to get on with others, to motivate others in a team
- **focused** on the goal
- **committed to the project**: having an active, positive belief in it
- **skilled in management**, with an ability to think strategically, chair meetings well, respect colleagues and lead effectively
- **skilled in negotiation**, to secure win-win situations
- **skilled in delegation**, to trusted colleagues, to avoid becoming stressed by taking too much on yourself
- **organized**: someone who is careless of sloppy in their professional life will not be a good project manager
- **highly numerate**: proficient with figures
- someone with **good business sense**, to keep an eye on costs
- someone with **an eye for detail**, who is thorough and meticulous (but see the next quality)
- **able to see the big picture**: someone who only sees details will quickly become overwhelmed and unable to see things in perspective and move forward
- **able to keep track of different processes** (keep several 'balls in the air') at the same time
- **proactive**: able to stay in control and think ahead
- **creative and flexible** in finding solutions to difficulties
- **able to document progress clearly**
- **good and resolving conflict**
- **patient and determined**.

9. WHAT IS A PLANNING?

Planning is a way in which we can come to grip with something complex and define certain matters in a structured way. Time spent on planning and preparation is time well spent.

As minimum, you need to define:

- **The separate stages** of a project: **what** need to be achieved?
- **The resources** needed for each stage:
  a) The personal required: who is going to undertake the tasks?
  b) The financial resources needed for each stage: how much is each task going to cost?
  c) **Other resources** [such as offices, computers and other equipment]
  d) needed
  e) **The time** when each stage will happen: **when** will the tasks be done?
- The following are also significant:
  a) The **quality** of what is delivered. A plan does not simply list different stages; all the expectations must be met. Effective procedures and standards need to be set to keep control of the project.
  b) The **risks** (uncertain events) that cloud affect the successful implementations of the project. The aim therefore is to identify such risks and do you all can do reduce the likelihood of their occurrence.

10. DIVIDE UP THE WORK

You know your overall aim, which might be ‘to update your website by 1st May’ or ‘to arrange a conference for mid-October’. You now need to break down this overall aim into manageable tasks.

When I go on a long-haul flight, I like to keep an eye on the progress. For example, on 13-hour flight I work out what percentage of the journey I have covered after, say, 45 minutes (6 percent), 1.5 hour (12 percent), and so on. Dividing up the overall journey time and measuring progress in a concrete way helps me feel I am on my way to reaching my goal. Similarly, breaking down the tasks in to smaller, more manageable activities enables us to know where we are in a project.

Analyse the project you defined in your scope of work, into manageable pieces (or chunks) of work. The name of such an analysis is a **Work Breakdown Structure** (WBS).

For example, you may need to plan a conference with an international speaker for next spring. You could divide the work up into smaller unites as follows:

(i) Received project go-ahead.
(ii) Book speaker.
(iii) Arrange venue.
(iv) Arrange accommodation and travel for speaker.
(v) Arrange publicity for conference.
(vi) Receive bookings.
(vii) Do admin.
(viii) Produce handouts.
    a) Make final checks: Check venue will provide projector
    b) Check speaker will bring laptop with presentation already loaded on.
(ix) Run conference.
(x) Evaluate at end.

Key this information on to a spreadsheet, or use a proprietary software program. Notice one key point in this list: each item (for example, ‘2 Book speaker’, ‘3 Arrange venue’) consist of a verb (action word) plus a noun (thing). Normally, when we make a list, we tend to think only of nouns – you probably put nouns in the pattern diagram. Adding verbs can be very useful as they express the practical action you need to do: arrange, receive, evaluate.

If you get stuck at any point, here are two hints:

1. Ask the question words why, how, what, who, when, where, how much
2. Being at the end and work backwards. In other words, start with what you need to deliver or produce and think of the deferent stages that have to be undertaken to meet that goal.

11. WHAT YOU WILL NOTICE

As you develop this list of tasks, you will notice several things:

- You can further subdivide each task into smaller tasks, so go ahead and do that. Your aim here is to list every significant task that needs to be completed. Again, try to write both a verb, such as identity, assess, collect, review, and a noun for each task.
- Although your aim is to list all significant tasks, you will not achieve that immediately, so go for successively more exact (‘iterative’) definitions of what you what to achieve. I remember, for example, sitting down with a computer software developer to define the requirements of handling large amounts of data on a major project I led. It took many meetings to define precisely what gradually towards the goal of a full specification.
- Each task will require for their information, for example about time and personnel.
- Resources – the subjects of the other parts of today.
- Some tasks are depended on other tasks, while other tasks are independent, for example, you need to book a speaker in advance of arranging publicity because you will want to include the speaker’s name and credentials on the publicity. On the other hand, booking the speaker and arranging the venue do not depend on each other.

12. SET A TIMETABLE

You've now listed the tasks, with many sub tasks, and you now need to add further significant information. You can add more columns to your spreadsheet to show the duration of tasks (in working days or hours) and start and end dates, or use a Gantt chart (named after the US engineer and management consultant Henry Gantt, 1860-1919). A Gantt chart has the added advantage that it also shows:

- Milestones: particular key dates
- Who is responsible for different stages?

Don't forget...

When planning schedules, remember to allow for:

(i) Holidays, both by individuals and public holydays .

(ii) Other work that individual might undertake at the same time. For example, a colleague might be compiling a report for another department on the days you have allocated for her to be available in your project.

(iii) Unproductive time. You may sit at your desk from 9 a.m. to 5 p.m. with breaks for lunch, but how much of the time is actively productive? All these factors need to be remembered. As a rule of thumb, I estimate that I work productively for about 1,500 hours per year. I arrive at this figure as follows:

52 weeks per year - 4 weeks of holidays - 2 other weeks (sickness, training)

=46 weeks.

I am at my desk 8.30 a.m. to 12.30 p.m. & 1.30 p.m. to 5.30p.m. = 8 hours but I only do productive work for 6.5 hours per day (the rest is routine admin, development work and checking accounts) = 32.5 hours per week. And 46 weeks x 32.5 hours = 1,495 hours.

13. ALLOCATE PEOPLE TO ACTIVITIES

So far you have listed all the activities in the order in which they need to be undertaken. You next task is to allocate people to those activities. At this stage, assign roles to the activities. You may well have certain named people in mind but here it is more important to allocate the activities to a particular job title.

You know exactly how long some activities will take. To travel to a city in another part of the country may take three hours. To fill in certain forms and go through certain procedures may take, say, ten hours. For other activities, the amount of time actually spent will depend on the number of colleagues working on the part of the project. For example, I think, I know that to check through 1,000 entries in a computer logging system will take one person four days i.e. if he or she will work through 250 entries per day. If I have four people all doing that same work, the amount of actual time taken will be about one day in duration.

14. ASSIGN TIME TO ACTIVITIES

We now move on to put figures of timings against the various activities listed. The aim here is not simply to pluck figures out of the air by not giving any thought to the question. ‘How long do you think that task will take?’ but to consider figures as accurately possible.

If you are unsure about how long an activity takes, try a sample yourself and check the time it takes. Taking the example above, you yourself could actually check 50 records and see how long that takes you. The assumption was 250 entries per day, so you think someone could check 50 entries in one – fifth of a day based on a 7-hour day [420 minutes] divided by 5 = 84 minutes.

But when you try it yourself, you find it actually takes you two hours (or 120 minutes). So, your original assumption of checking 250 records in a seven – hour day is at extreme [50 x 5 = 250] x 2 hours =10 hours = about 1.5 days, rather than the one day you originally thought to work for 250 records. Some activities may well take considerably longer than you think. For example, you think arranging a venue for a conference may only take an hour, but that will be the time needed when you have chosen the actual location. You may spend several hours investigating venues on the Internet and then two days travelling to various locations in your city to see what each venue has to offer.

One way of noting times is to list both estimated and actual figures. This has the advantage of enabling you to learn from experience on future occasions, when you can look at the actual times taken in contrast to the estimated ones.

15. ALLOW FOR CONTINGENCIES

As well as allowing time for holydays, illness and administration, you need to allow time for:

1) **Project start – up:** If you are given the go-ahead on 10 May, if may not be 10 or 11 May that you actually start. You may need to complete other work first. This also applies to induction of new members of staff, briefing colleagues you may outsource work to, installing new computer software and setting up offices.
2) **Between times:** These are the times between events happening. For example, a factory may delivery 5,000 CDs to a warehouse but it may be one week between the time when they are delivered and the time when they are sent out to distributers. So, you need to make allowance for that week. Another example of 'between time' is the time taken between first drafting a report to when it is approved by the project board or a company's senior management or directors.
3) **Unplanned events:** Projects often overrun because you have not built in contingency time. Contingency time is time that you include as a necessary part of your overall schedule to allow for unplanned events that could significantly delay your project.

4) Managing risks: Risks need to be identified, assessed and then dealt with. The key point to remember is that you will not survive a project without encountering certain risks, so it is better to plan to deal with them rather than be surprised when they unexpectedly arise.

5) You should prepare a risk-assessment document that lists potential risks, their probability of occurrence, the extent of their effect on your project objectives and your responses to them.

16. WHY FINANCIAL RESOURCES ARE IMPORTANT

Financial resources are significant in project management in two areas:

1) **In the planning stage**, ensuring that your estimates are as precise as possible. This means that they are:
   (i) Accurate, not vague
   (ii) Based on measured takes, that is, ones that can be quantified, not approximate. Of course, in the planning stage, you cannot be absolutely exact, but your aim should be to be as precise as possible.
2) **In the implementation stage**, ensuring that your costs are managed and controlled as rigorously as possible. This means:
   (i) monitoring costs incurred
   (ii) authorizing any additional costs that are necessary

Costs should be considered at every stage of the project:

1) **In the thinking stage.** This is when you conduct a feasibility study considering think likely costs against the expected benefits in order to make a business case.
2) **In the planning stage**. There are three points here:
   (i) Your preparation of a Work Breakdown Structure (WBS), taking your estimates (which are as precise as possible) of the time each activity will take and working out the costs from that.
   (ii) Your calculations of any income that may come in to the project, for example, if you are holding a conference, not only will you incur costs such as venue and speakers' costs, you will also receive income from participants
   (iii) Your discussions of contracts. If you are involving outside suppliers, you can assess their offer and evaluate the price they will charge. You should also consider the dates when payments will be made to ensure that you have a good cash flow

3) **In keeping to the project budget**. When you have estimated all your project costs as precisely as possible and confirmed any contracts for outside suppliers, you can gain approval and confirmation of the costs of the project. You can then use such costs as a basic against which actual costs can be compared during the project's implementation and evaluation.
4) I**n controlling costs** when the project is being implemented. You do not want expenditure to escalate out of control so you need to have in place systems and procedures for tracking expenditure, that is, monitoring costs, analysing any deviations and, where necessary, giving the authority to make additional expenditure.
5) I**n evaluating the project.** At the end of the project, you can check the final costs against the original estimates and also make sure that the planned return on investment has been met.

17. WORK OUT THE COST OF YOUR PROJECT

For the **work breakdown structure** [WBS], you can begin to assign costs. As part of that task you will need to decide who will undertake the work. Will the work be done by:

- you?
- colleagues in your department?
- colleagues in other departments in your company or organization?
- an outside supplier?

For each of the above, you will need to know the hourly [or day] rate of the people concerned. You will also need to check to what extent company overheads are included in your project is charged to colleagues from another department your company or organization.

Using outside suppliers

If you decided to outsource to outside suppliers, for example if they have greater expertise than your in-house staff, you will need to brief them on the précis work required. This brief should include such obvious matters as schedule, statement of work required and payment, and also less obvious but important matters such as a statement of the ownership of the work. For example, if a freelance author is being paid a fee for writing a test, then you should prepare a statement on whether he or she retains ownership of that text and what publishing rights he or she is granting to the company or that text and what publishing rights he or she is granting to the company or organization he or she is working for.

Remember these things to build into your budget:

- Time to brief a range of possible suppliers
- Time to evaluate their bids and reach a decision on which supplier to choose
- Time to brief the supplier at the outset of the work [‘start-up’ time]
- Time to administer and keep track of their work
- An approximate level of contingency to handle risks and other uncertain events that will arise.

18. DEVELOP A PROCUREMENT POLICY

Procurement is the term used to decide the process by which goods and services are obtained by outside companies or organizations. The following factors should be considered:

(i) The **authority** of those making decisions on awarding contracts. The colleagues who make decisions on whom to award contracts to should undertake their work with professional integrity and fairness

(ii) The criteria on which decisions are made. When evaluating and awarding contracts you should be as objective as possible when comparing price, delivery dates and the financial soundness, reliability and previous experience of the company or organization

(iii) The **terms and conditions** of a contract. As the saying goes, 'the devil is in the detail'. Look at the terms and conditions, especially those concerning delivery of goods and services and dates of payment. If you are uncertain about anything, ask.

Decisions, decisions

As part of your planning, you should decide on the kind of contract you want to offer to an outside supplier. Is it a fixed contract [for example, building a website] or does it involve regular maintenance [for example, maintaining a website or providing security in a office building]?

If you are considering using a supplier you have not worked with before, visit their offices and get to know their staff, and/or ask for reference from previous companies or organizations that have used their services before. Do not simply rely on their website.

19. FINALIZE THE PROJECT BUDGET

(i) Make sure you have included the cost of:

- Colleagues: the time spent by your colleagues, colleagues in other departments, colleagues in outside companies or organizations, including start-up and administration time
- Equipment or facilities needed for the project, such as computers or offices
- Other human-resource costs such as recruitment and training
- Other departments' costs such as IT and marketing.

(ii) Your budget should also include:

- Cash-flow predictions during the whole of your project
- Any income forecasts that are parts of the project
- The 'cost centres' to which particular items of expenditure will be allocated during the implementation of the project
- Contingency: a figure of about 10 per cent of your total costs is often suggested.

20. WHY QUALITY IS IMPORTANT

So far, we have considered the role of financial resources and their significance at every stage of a project (planning, implementation and evaluation). However, while keeping to your budget is a vital part of project management, it is by no means the whole story. As the following example shows, accepting low standards of quality results in more work: if you accept work of a poor standard, you will have to unravel all the difficulties caused. You will lose valuable time and delay the project.

(i) How can you achieve quality in your project?

Here are some practical tips:

(a) Make quality something you can measure: 'Quality' can be a vague term and it can mean different things to different people. This is why you need to define specific objective criteria by which to measure quality.

(b) Be concerned with be customers'/users' requirements: They are the ones for whom you are managing the project and who receive its end result. If matters come to a disagreement, what are the non-negotiable aspects that the customer must have?

(c) Focus on what is delivered rather than on the process of how you achieve that end: For example, I was recently in charge of a project to deliver 5,000 books to an exhibition in the UK in March. We delivered the text to the printers on schedule in October, but were delayed by packaging difficulties, which means that with shipping time the books would not reach the UK until April. We therefore had to send the books by air freight to meet the March deadline. The result: a satisfied customer: we delivered what we said we would. We focused on fulfilling the customers' expectations, even though incurred higher costs of air freight.

(d) **Build in quality reviews at every stage:** Quality isn't a 'nice-to have': it's an essential. Discuss and agree how quality can be measured objectively regularly through the project.

(e) **Ensure that skilled and experienced colleagues conduct the reviews.**

(f) **Put effective procedures in place that report on quality of performance:** If necessary, improve your working methods during the project.

(g) **Where necessary, include outside consultant to review quality and follow best practise within your industry:** For example, on one project I led, all was going technically well internally with a project until a meeting with outside consultant reviewed our work and criticized it for being below standard. We had to reassess our working methods to put the project back on track. Outside consultant have the advantage of not knowing the internal politics of your workplace and they can see directly into a situation that you might for different reasons be unaware of.

(h) **Do you best now:** All this talk of quality can seem abstract. It is up to each one of us to do our best with the work that we have to do right in front of us now. We may only play a small part in a large organization but it is our responsibility to produce quality work now, rather then think 'I can't be bothered' and have to sort out problems in a few weeks' or months' time.

(ii) Confirm commitments

As you launch your project, you would be wise to confirm key commitments of:

(a) **The main people concern with running the project:** Check that they all can start on a certain date or as soon as possible after that time.

(b) The other stakeholders: It is best not to assume that they are fully in the picture: communicate with them the status of the project.

(c) The available financial resources: You and your colleagues will want to be paid properly, and you need to ensure that any outside suppliers are paid punctually.

(iii) Put in the writing

Make sure you have confirmed in writing the availability, roles, responsibilities and authority of the key stakeholders. It is particularly important to define the activities that each colleague needs to undertake. Look at your **work breakdown structure** and make sure that it defines:

- the work to be undertaken
- the start and end dates
- key milestones, for example: when certain proportions of the work – such as a quarter, half, three- quarters – are completed when a certain level of income has been achieved when a certain output has been delivered and accepted by the customer/user timing of expenditure [costs] and any income received.

21. TRACK, CONTROL, REPORT

The key aspects of managing a project during its implementation are tracking, controlling and reporting:

- **Tracking**: you need to have in place procedures to monitor actual progress against what you had planned. This is so that you can be aware of any slippages or delays as soon as possible so that you can inform your customer of a possibly later delivery date
- **Controlling changes**: any changes that you have recorded by monitoring in the tracking stage can be evaluated and corrected. For example, you can see whether a delay is significant and thus likely to effect the critical path of whether it is relatively unimportant.
- **Reporting changes**: you need both to record changes to the work breakdown structure or similar project initiation document by updating the project status and also to inform the key stakeholders of significant changes in the project, for example at regular progress meetings. We know look at implementing these processes.

22. DEALING WITH THE RISKS

We defined risks as uncertain events that could affect the successful implementation of a project. Your aim should be to identify such risks before they occur and do all you can to reduce the likelihood of their occurrence and minimize their effects.

We also identified the need in the planning stage to prepare a risk-assessment document. This document should list potential risks, their probability of occurrence, the extent of their effect on the project objectives and your responses to them.

It is important to consider possible risks. For example, a company might launch a new technological product that is a smart phone or an e-reader. Since technology is changing fast in these areas, significant changes in the marketplace are likely, leading to changes in demand and consequently potentially to significant lower return on investment.

It is important to record risks and the action taken to resolve them. You should review risks regularly. A record of risks is called a **risk log** or a **risk register.** Typically, such a record consists of:

- Risk ID number: a unique number to identity the risk
- Identifier: the colleagues who raised the risk
- Date: the date on which the risk was first identified
- Description: a brief but clear description of the risk
- Probability: the likelihood of the risk's occurrence – low, medium or high
- Effect: the impact of the risk on the project – low, medium or high
- Response: measure taken to counteract the risk
- Owner: the colleagues assigned to deal with the risk
- Status: whether the risk has been delayed or not.

Risks may develop into issues – significant matters that will jeopardize the completion of the project. Again, such matters should be identified, logged and assessed, and action planned and agreed. To deal with these, you may need to identify and have authorized additional resources. You will then need to monitor

23. CONTROL YOUR COSTS

To ensure control of your costs, you need to:

- **Keep to the agreed budget**: If additional expenditure is needed, you should have allowed for it that in your contingency funds. If not, you will need to present a good case to senior management for extra funding.

- **Make sure all expenditure is carefully recorded**: This includes costs of staff and equipment [e.g. computers, offices] – that all expenditure is regularly assigned to cost centres and that you monitor such expenditure regularly. Normally, expenditure is tracked monthly, with progress reports being given at three-monthly intervals.

- **Make sure that any income is also carefully recorded**

- **Prepare monthly summary statements** that include:
  - The overall actual expenditure and income incurred up to a particular point, set alongside the total project budget
  - The costs incurred in the period under review
  - The cost incurred since the beginning of the project
  - The percentage of the work completed.

24. PLAN FOR CHANGE

Since there are likely to be changes during the lifetime of your project, you will need to take steps to minimize their effect. Ways in which you can minimize the effects of change include:

- **Preparing a disaster recovery plan**. A disaster recovery plan is a document your company or organization should have in place in case of a major incident such as extreme weather, a fire at your offices or a major terrorist alert. This should list contact details of staff, insurers, major suppliers and procedures to be followed. For example, if there is a severe weather warning, a prolonged transport strike or a major terrorist alert, staff should able to work from home with remote access to their computers. By having procedures – such as for backing up computer files in place before an incident occurs, you can minimize the effects of disruption.
- **Recording roles and responsibilities**. If a key member of your project team unexpectedly resigns or suffers a major illness, then you will at least be aware of that colleague's responsibilities and can adjust team members accordingly.
- **Dealing with internal changes to the project.** For example, you may encounter technical problems or your customer may change his or her mind (for example, while you are redesigning their website they may now think it would be a good idea if you could also help them improve their online ordering system at the same time). In such instances, base your decision about whether to make the change on the following information:
  - The source of the request for change
  - The reasons for such a request
  - The effects of making such a change, for example on schedules, products and resources, and the effects of not making such a change
  - The cost of making such a change.

Scope creep

The term **scope creep** refers to a series of gradual small changes to a project that together have a significant effect on it. Examples of scope creep are:

- Activities not included in your original plans, for example where colleagues are made that they consider minor changes without formal approval
- Activities that take longer or cost more than originally planned.

You can control scope creep by:

- Identifying the significant activities more effectively earlier in your planning
- Assessing the effects of requested changes more thoroughly [see above]
- Developing good relationships with your key colleagues so that your communications are better.

25. KEEP GOING!

There comes a time in a project, when you have all your systems in place and everything is going more or less smoothly, when you begin to wonder if the project will fail. At such a time, it is worth following these tips.

(i) **Remain calm and determined.** You have in place all your systems. Be confident that they represent effective work procedures.

(ii) **Stay focused.** If problems do develop, be positive and focus on a solution rather than seeking to attach blame on an individual.

(iii) **Don't get immersed** in the details that you miss out on the big picture. See how far you have come as well as how far you still have to go.

(iv) **Think of the next step.** To consider that, reassess the planned time estimates and if necessary, change them in advance, rather than discover too late that they were inaccurate.

(v) **Look at your end product.** I have worked on several multi-year large projects to produce major reference books. During the lengthy development periods of these projects, I imagine a picture of me holding the final product in my hands this helps keep me going.

(vi) **Communicate well with others** – both in your team and with your stakeholders

(vii) **Think creatively** about ways you can work even more effectively. Be sensible. Are there even better ways to work?

(viii) **Deal effectively** with what is before you. Remain positive, well-motivated and committed. Do your best now.

26. LISTENING

Listening may seem a strange place to start, but as is often stated*, "God gave us two ears and one mouth"*. So, before we're tempted to speak, it's wise to listen. You need to listen at every stage of the project.

(i) In the **preparatory stage** of thinking, you need to listen to your customers' or users, needs so that the content of your project matches their requirements.

(ii) In the **planning and costing stages** as you continue to lay a string foundation, check that the colleagues you work with understand you and one another.

(iii) In the **implementation stage,** you need to listen to your customers or users in case they want changes to the project, and to colleagues are they work out their roles. Are they struggling to understand the brief you have given them? Shouting more loudly at them won't help – you need to listen.

Some effects of listening

(i) Focuses on the other person. Often when someone else is talking, we're focusing on thinking about what we are going to say as a reply. Stop and really listen to what the other person is saying. Make eye contact with them. Rephrase what they've said in your own way to help you clarify the meaning in your own mind (for example, 'So what you're really saying is that the whole process needs to be looked at again'); this process is called 'reflective listening'.

(ii) Values the person you are listening to as an individual in their own right, so that you understand 'where they're coming from', why they are working or speaking as they are

(iii) Means that you do not listen only to the words a colleague is speaking: you can perceive their response to what you are saying by being sensitive to their body language and tone of voice.

(iv) Allows to you 'listen between the lines', to become aware of any underlying messages – your response could be, for example, 'So I guess what you're saying is that you need someone else to help you complete this task on tome'

(v) Builds trust between people: you show that you are genuinely interested in them.

This forms the basis to help you work well with them.

The basics of communication

Next, we will discuss the basics of communication under the heading A I R:

(i) **Audience**: We adapt what to communicate according to our audience. So, for example, an email to a colleague at the next desk to us to will be written in a different tone from one to the company's managing director.

(ii) **Intention**: What exactly are you trying to communicate? What is your message? If you are not clear about it, the readers of your email won't be clear either. For instance, on one of professor's courses, a participant's key message was buried in brackets at the end of a 67-word sentence!

(iii) **Response**: What are you expecting your colleague to do as a result of your communication with him or her? Have you made clear what you want your colleague to do next? You don't want them to say, 'Yes I get that, but so what?'

A communication plans

It can be helpful to draw up a communications plan. This list includes:

(i) The **person or group** you need to communicate with

(ii) The king of **information** you need to communicate

(iii) The **purpose** of the communication: for example, reporting progress, email etc.

(iv) Meetings, reports, phone calls

(v) The **frequency** with which you will communicate the information.

27. DELEGATING WORK

In briefing or in delegating others, you need to:

(i) Choose colleagues who are experienced and skilled enough to take on the task;
(ii) Otherwise you will need to provide training for them be clear about the task or activity that you want your colleague to undertake
(iii) Where possible, follow up any spoken instructions in writing with a full brief, outlining the work
(iv) Break the task or activity down into its parts. Write briefing instructions, but don't
(v) Just write in abstract terms; give examples of what needs to be done
(vi) Give background details, so that the colleague known where their task or
(vii) fits into the overall scheme of things, without however, giving an exhaustive account of all the details
(viii) provide an opportunity for your colleague to ask questions to clarify what you want them to do state the date and time by which you want your colleague to complete the work
(ix) Supervise their work properly: provide the equipment and other resources that the colleague needs. Discuss any difficulties that arise, together with possible solutions.
(x) Monitoring their progress during the project and evaluate it at the end of the project.

(I) Emails

Emails are great: we can communicate with colleagues all round the world instantly. But emails al so have their disadvantages. We can receive too many unwanted once that stop us dealing with the tasks we are supposed to be dealing with.

Here are a few tips:

i. Put a clear subject in the subject line: this will help your reader know what the email is about.
ii. Use ‘cc’ (‘carbon copy’, from the days of paper) and ‘bcc’ (‘blind carbon copy’)
iii. Sparingly. Only send copies to those who really need to see the email.
iv. Unless you are writing to a close colleague, include some form of opening and closing
v. Greetings. The policy of your company and organization and your own personality will guide you to what is acceptable [for example, I find ‘Hi Martin’ difficult to accept from
vi. Someone I don’t know at all].
vii. In a long email, put the key information at the beginning so that it will be clear on the
viii. Opening screenshot as your reader opens the email.
ix. Use abbreviations that are generally known, not obscure ones.
x. Don’t use capitals, which indicate shouting.
xi. Include other contact information at the end of your email [including your job title,
xii. Phone numbers [landline, mobile] and postal address]. Your reader might just want to phone you clarify a point.

As with all forms of communication, check that what you are saying is accurate before you send it. We’ve all received emails inviting us to a meeting on Tuesday 14 September, only to discover that 14 September is a Wednesday. The result is that many colleagues spend precious time emailing requests for clarification, and then time has to be spent responding to them with the exact date. It would have been better if the person who originally sent the message had checked the details before sending it.

(II) Reading emails

Try to discipline yourself to opening and responding to emails at just a few points during the day, rather than having it on all the time. In periods that required concentrated work, switch your emails off. The time taken to open an email and then I'll just reply to this now I've opened it' adds up and can have a significant effect on your overall work.

(III) Meetings

Sometimes it seems as if life consists of going from one meeting to another, without actually achieving anything. How can we make sure the meetings we attend count? We can consider:

- The purpose of meetings
- Preparing for meetings
- Chairing meetings
- Participating in meetings
- Following up from meetings.

The purpose of meetings

Meetings are useful to:

– give colleagues **information**, for example about a new proposal or progress
– discuss **issues** with colleagues, for example about negotiations on the terms of a contract, the way ahead or a solution to a problem
– reach a **decision** and agree on the next steps to be taken.

The key to a successful meeting lies in the preparation. It is essential that you prepare in the following ways:

(i) **Know the purpose of the meeting**. May of our meetings have no clear purpose and could easily be shortened or even cancelled. You need to be crystal clear about what you are trying to achieve.

(ii) **Plan a venue and time** [start, finish,] in advance. I've been to meetings at the stated venue but arrived there to find that the meeting is in a different place.

(iii) **Invite the key people** to participant well in advance. If you want a boss with a busy diary to be present, it is no good inviting him or her the day before; you need to have invited them a long time before. It is also useful if you can discuss with key people in advance any agenda items that could be controversial.

(iv) **Circulate an agenda in advance**. This means that you will have thought about the structure and purpose of the meeting beforehand. Also, circulate important papers with the agenda. Not at the meeting itself. Ideally, the length of such papers should be no more than one page.

(v) **Prepare the meeting room**. Plan the seating: chairs around a table invite discussion; a chairperson at the end of a long table with ten seats on either side, less so. If a PowerPoint presentation is being given, ensure that you have a projector and connecting lead set up. Check that the heating or air conditioning works.

(vi) **Read reports in advance**. If reports have been circulated before a meeting, read them. I have been in too many meetings where we have sat during the meeting reading material, something that should have been undertaken in advance.

(vii) **Ensure that you come up with accurate information**. If the meeting is one to monitor progress, take all your latest date on progress with you.

Chairing meetings

The chairperson – or chair – is the one who sets the tone for the meeting and guides the participants through the discussion. His or her tasks include:

- keep to the agenda so that the meeting finishes on time
- bringing in key individuals to contribute at appropriate points
- summarizing progress
- drawing together the points discussed, to reach conclusions and to make decisions (if a point has been controversial, the chair can express exactly what is to be eliminated, to avoid possible misinterpretation later)
- ensuring that action points are clear, particularly for those responsible for following up particular points. The action points should be SMART: specific, measurable, agreed, realistic and timed [see also Sunday]

A good chair is a diplomatic and organized leader, someone whom the colleagues trust, who values, motivates and involves others. Ideally, he or she will be able to quieten those who talk too much and draw out those who talk too little. He or she will sense when the time is right to bring a discussion to an end and be able to come to clear decisions

Participating in meetings

Everyone has a part to play in a successful meeting. I have never understood how people can come out of a meeting asking, “What was the point of what?” when they themselves have not contributed anything. Each of us has a role to play by:

(i) listening well and concentrating: switch off your phone; avoid sending text messages

(ii) Asking for clarification: if we are unsure about a point that has been made, it is highly likely that other colleagues are too, but have been afraid to ask for fear of looking ignorant.

(iii) Being constructive: even if we disagree with what has been said there are positive ways of expressing a difference of opinion without angry criticism of the other person.

(iv) Confronting issues: focus on the real issues: too many meetings avoid discussing “the elephant in the room”, the subject everyone is aware of but which is not discussed because it is too uncomfortable – don’t get side-tracked!

(v) Being willing to change your mind: if you are listening and persuasive arguments have been offered, allow yourself to be convinced by them and change your opinion about an issue.

Following up from meetings

A meeting is a waste of time if decisions were made but no one acts on these decisions. If colleagues have action points to pursue, they should follow them up. The **minutes** of a meeting are a record of what happened during the meeting, especially its action points. The person taking the minutes does not need to write down everything that goes on, but must note specifically the significant decisions, especially those concerning dates, schedules and financial matters.

The sooner the minutes of a meeting are circulated to those present at the meeting and other key colleagues, the more likely it is that colleagues will follow up the action points asked of them.

A good project leader will also follow through on progress of the key action items; he or she will not leave it to the next meeting, only to discover that action has not been taken and valuable time has been lost.

(IV) Progress reports

As project manager you will need to update your steering committee or project board and other colleagues regularly. Your reports should:

(i) Be presented in a standard format every time, not one that varies. Consider using different colours to indicate various aspect of your project, for example the different stages.

(ii) Contain a summary of the project's overall progress.

(iii) Contain all the significant facts relating to a stated time period; for example:

   a. Actual work undertaken, the stages, usually in hours
   b. Actual costs incurred
   c. Actual expenditure made particular achievements, such as milestones or other targets reached

(iv) Variations from expected figures in terms of work [output, products], timings, costs and payment

(v) Reasons for variations from original or approved estimates, for example explanations of delay or excessive expenditure

(vi) Other issues [including any risks from your risk-management procedures], including,

(vii) where possible, statements of the action to be taken to solved them

(viii) A forecast of the new final projected date and costs, on the basis of the information in your progress report

(ix) A note of changes approved

(x) A plan of the significant outputs and achievements that you are planning for the following reporting period, together with a note of possible difficulties you expect to encounter and how you will resolve them.

Put it in writing

As with any other form of communication:

(i) Think about your audience, intention and response [see 'The basics of communication', above]. This will determine, for example, how much information you should include in your reports. If in doubt, discuss with colleagues.

(ii) Make sure your message is well planned and well structured

(iii) Write clearly and, if possible, simply, using only those abbreviations and technical expressions that the readers of your report are familiar with.

(iv) Be as concise as possible. You may have heard of the quotation, *'I have written you a long letter because I don't have time to write you a short one.'* Writing concisely is an art to be learned – but it is very useful. If the report is long, present a one-page summary at the beginning.

(v) Use correct grammar and proper punctuation. Shortage of time is no excuse for using careless or sloppy English or the forms of abbreviation (textspeak, SMS language) you use for close friends.

(V) Teamwork

We're used to thinking of teams in the contexts of sports. The project manager is the leader of a team, and as such is responsible of certain actions, as follows.

(i) Choose the personnel, especially the key colleagues, carefully choose colleagues who are skilled and experienced or those who can develop well with training. Having inexperienced staff on the team will affect the team and mean that you have to spend undue amounts of time helping them.

(ii) Be clear about the goals. Keep your team members informed, about the bad news as well as the good. Plan your persuasive arguments well. Present them strongly, with inspiration and realism.

(iii) Work out the different roles and responsibilities of team members, according to their skills and abilities. Using the Belbin approach to team role analysis is a useful way to think about this. (An awayday for a group I'm connected with I ended up re-discovering my chairing skills, so I was formally asked to chair meetings.])

(iv) Set a consistent example. For example, your colleagues will lose motivation if you ask them to work extra hours when you often leave promptly or early. Model the qualities being available, listening well – that your trying to encourage in others. Practise what you preach.

(v) Respect others: appreciate their contributions, recognize individual team members, Achievements publicly. Keep working on your professional relationship to develop trust.

(vi) Set targets that make the teamwork hard but that are not totally unrealistic (colleagues recently asked me to undertake 87 days' work in 10 days!)

(vii) Be flexible about that is negotiable and about different style of working. Be prepared to 'think outside the box' creatively to challenge existing patterns of thinking and working and find solutions to difficulties.

(viii) Stay focused and determined to complete the task. [Colleagues have been impressed that I have completed three multi-year project – each five to seven years in duration and feel inclined to trust me with similar projects in the future

(ix) Deal with conflict quickly, tackling the issues: don't be too cautious and fearful about speaking directly and clearly about difficulties. There is no need to do this all the time, however: you need to balance out this quality with ones that show empathy.

(x) Be fair and treat all your colleagues equally, even though you may like some more than others. Reward your team in an appropriate way, for

example by taking them all out (with partners) for a celebration meal at the end of the project:

(VI) Resolving conflict

How to Discuss What Watters Most by Douglas Stone, Bruce Patton and Sheila Heen (Michal Joseph, 1999) and The Peacemaker: A Biblical Guide to Resolving Personal Conflict by Ken Sande (Baker, 1991) helpfully suggest how you can resolve conflict, as follows:

(a) Distinguish the incident – what happened – from feelings about the incident. Consider separately: The incident – someone said something; someone is to blame. Try to focus on the real issue, and understand other people's interests as well as your own

(b) Feelings about the incident, such as anger or hurt the identity of the other people involved, including their self-worth, which may feel threatened; calmly affirm your respect for them.

(c) Do what you can to resolve the issue and maintain the relationship if possible: prepare and evaluate possible solutions.

(VII) Negotiate: win-win situations

In negotiating, we are aiming for a win-win situation. (This is different from behaviour where one person wins at the expense of another's loss.) A win-win situation can perhaps be well illustrated by an example. My son Ben has just moved to Asia and he wanted to sell his camera. His friend Rob wanted a camera to take photographs on his travels. Ben sold Rob his camera, so both won: both gained what they wanted: Ben money, Rob a camera.

In his book Seven Habits of Highly Effective people, Stephen Covey points out that the basics of a win-win situation is our character: 'If you're high on courage and low on consideration, how will you think? Win-Lose. You'll be string and ego-bound. You'll have the courage of your convictions, but won't be very

considerate of others... If you're high on consideration and low on courage, you'll think Loss-Win. You'll be so considerate of others' feelings that you won't have the courage to express your own... High courage and consideration are both essential to Win-Win. It's the balance of the two that is the mark of real maturity If you have it, you can listen and you can empathically understand, but you can also courageously confront. 'Seven Habits of Highly Effective People Personal Handbook,

28. PROBLEMS THAT MAY ARISE

The main Problems that may arise during your management of a project often occur because of poor set-up or implementation.

(i) Problems with poor set-up

If your project was not though carefully enough at the outset, problems can arise. These problems may be due to such things as:

(a) Aims that were defined only vaguely, not precisely.
(b) Weak support and commitment from senior management. If senior managers are half-hearted or unenthusiastic about the project, their lack of influence will be contagious.
(c) Lack of ownership by stakeholders. Unless the stakeholders are committed to the project, it will fail
(d) Inadequate experience and skills on the part of team members. You thought that colleagues' knowledge and abilities were far greater than they proved. Poorly defined roles and responsibilities, resulting in confusion. No one knows who is supposed to do what [see Monday and Thursday] Insufficient resources [especially financial] allocated to the project. The resources needed were significantly underestimated.
(e) Unrealistic estimates in the original plan.
(f) Weak leadership

(ii) Problems with poor implementation

If may be that project was thought fairly carefully at the initial stage, but has failed at the implementation stage. The following problems may then arise:

(i) Team members are not available at the correct times to undertake the work.
(ii) The schedule slips because inadequate or ineffective monitoring and control procedures are in place.

(iii) Unforeseen technical problems arise during the course of the project.

(iv) Unexpected risks occur that have a significant effect on costs and schedules.

(v) Bad communications, poor relationships and a lack of teamwork are significant.

(vi) Significant changes occur during the project that cause it to fail.

(vii) The end users do not fully accept the project's outcomes.

(iii) Getting your project running again

If your project has lost momentum or has seriously been derailed, all is not lost. To get it back on track, you need to focus again on:

- **The project's purposes:** Record your goals and aims. Look at your users and your original outcomes. If necessary, modify them. Make sure your new aims are SMART.

- **The project's personnel:** Look again at the project team and make sure the roles and responsibilities are clear. Deal with any relationship issue that may have emerged. Obtain the specific, focused commitment of every member of the team to complete the project. Do you need additional personnel to complete all the tasks on time? If so, cost them in, gain approval and ensure they are assigned to the project as soon as possible.

In particular, make the key personnel in the project more accountable by:

- Obtaining the agreement of a colleague's supervisor so that the colleague can work on the project for the specified duration.
- Clarifying carefully the work that needs to be done. (I recently delegated some work to a colleague and thankfully and allowed myself quality time to write a briefing document, which took me two hours to prepare. But because

I was specific on the tasks, outcomes, time required and date by when I wanted the work completed, delegation of the work was effective.)

- Gaining colleagues' agreement on the monitoring of their work. [This isn't' checking up on someone' as if you don't trust them; this is part of the project. Done properly, it shows that you value that person and their work; it may also help you recognized warning signs if difficulties do ask you questions.]
- Valuing colleagues' work then it is well done and affirming them in front of other people. Such tokens of appreciation even a simple 'Thank you' are important.

(a) **The project's stages:** Redefine what needs to happen at each stage. Record the activities that still need to be undertaken. Add new activities; confirm inn writing, delete or alter the activities that are still outstanding. For each activity, as accurately as you can, record personnel, time and resources especially financial required.

(b) **The project's schedule:** Adjust your original schedule so that it now aligns with any revised projected date for the conclusion of the project. Set fresh milestones key target dates in the project.

(c) **The quality of what is delivered:** Put in place measurable and objective criteria against which you can assess the quality of your outputs.

(d) **The project's risk managements:** If you have lapsed in logging (recording) risks, re-engage in this. Identify, assess and deal with further possible unforeseen events so that their adverse effect on the project will be as small as possible.

(e) **The project's control systems:** If the reason your project went off track was that you had inadequate monitoring and control procedures, you know need to make sure that you track actual activities against your revised plan and then effectively resolve any further issues that may arise.

29. CHANGE MANAGEMENT

Another key aspect of project management is change management. Whether your project is large – such as restructuring a local authority to perform more effectively – or small – such as renovating a community centre – ultimately a key part of what you are doing is managing change. If progress on your project has slowed down significantly, for example, and you want to increase staff motivation, you will need to move your colleagues on from the 'We've always done it this way' way of thinking, which may be firmly embedded in their culture.

(i) Responses to change:

(a) **People don't like change**. 'We've always done it this way' is the mantra they may repeat. 'Things worked as they did – why do we need to change?

(b) **People are uncomfortable with change**. Many people like routine and their patterns of life will undergo changes if changes are brought in.

(c) **People feel threatened by change**. Changes may affect a colleague's identity. If a shop – floor worker is promoted to management, he or she will have to work through issues of his or her personal identity because they are no longer 'one of the lads' [or 'lasses'], no longer part of 'us' but now 'them'.

(ii) Leading change

Here are some of the keys to leading change:

(a) **Understand your organization:** What is the organization's general atmosphere? Where are you? Is there a climate for change? Is the prevailing mood one of positive confidence, a 'can-do 'supportive mentality, or are attitudes negative and cynical with a lot of backbiting and infighting? Be aware not only of what is going on at the centre of your organization but also at its edges and what is not [or no longer] going on. Talk to your colleagues and, even more importantly, listen to them.

(b) **Emphasize the vision, the goal:** Don't get side tracked with minor issues. Your company or organization's mission statement may be

concerned with serving the community but that focus may have got lost. Refocus your key stakeholders' vision on that goal so that they understand it.

(c) **Emphasize the vision, the goal [again]:** I have deliberately repeated this line from the previous paragraph because, again and again, in managing change, you will constantly need to explain why you are doing what you are doing.

(d) **Convince colleagues that there must be change:** You will want commitment to change from senior management, the project team and your customers or end users, who will be affected by the changes. You need to example clearly why changes are needed [for example because of falling productivity or decreasing profits as companies are choosing your destination]. You also need to show colleagues your destination, where you are aiming to lead them and the benefits changes will bring.

(e) **Develop fresh values:** Turn tour vision and goal into values that determine the emphasis and ethos of you company or organization. Make them as practical and simple as possible. Writing course for a group of leading police officers and kept on asking them to simplify their values in ordinary words. It took two hours, at the end of which the boss said, 'Martin, you've changed my writing style in two hours!'] You could perhaps develop the former values of your company or organizations or you may need to rework them totally.

(f) **Develop a strategy:** As we have seen earlier this week, preparation and planning are essential, and so they are when we view project management from the approach of change management. It is vital to have a good strategy in place that will move you from your vision to your goal, through your values, to help earth your plans in reality.

(g) **Involve your colleagues:** In the early days of change management, involve the colleagues who will be part of the changes. Don't leave them 'out in the cold' or 'in the dark' till later: involved them in setting the vision and strategy and in making decisions.

(h) **Demonstrate committed leadership:** When you are trying introduce change in an organization, it is vital that this is not Seen as only one person's favourite subject. It is essential that the leader of such Change gather round him or her a group of other leaders who share that vision and a commitment to make it a reality. The senior leaders need these leaders to spend time with middle managers to make sure they catch the vision, so that the change can then be implemented throughout the organization.

(i) **Communicate well: A**s we saw on Thursday, good communication is essential in a project, and even more so when you want to move an organization through change. Rumours about possible changes to people's jobs, roles or location can all too easily arise and these can lower moral and lead to poor motivation. While formal public communications are significant, the informal, passing-in-the-corridor type conversation are also important. A boss who is always silent and remote and who only ever issues public announcements and trusting relationships in an organization. Friend of mine deliberately allows extra time on a visit to the farthest end of his organization's workplace so that he can stop and talk to people on the way. Such informal communication – even a brief but genuine 'Good morning – how are you?'

(j) **Recognize achievements and efforts:** Celebrate milestones. One club I'm involved with in my spare time celebrated the initial decision to change with a meal for the committee in a restaurant.

(k) **Stay focused on the goal, but be flexible on the way to reach the goal:** Keep stating the goal and why there need to be changes but be willing to negotiate on the detail and style in which colleagues can reach the goal, so that they feel fully involved. Don't get side tracked or deflected from pursuing your main goals by colleagues who want to make small unimportant changes.

(l) **Go for quick wins:** Find an aspect of change that can be implemented fairly quickly and will produce the results you want, to demonstrate to the wider audience that change is happening and to bring about a positive response.

30. COMPLETING YOUR PROJECT

As the project draws to completion, keep:

(a) Tracking progress against your original plans.

(b) Monitoring and dealing with changes, especially to schedules and costs dealing with risks.

(c) Controlling your costs.

(d) Focused on your end goal: providing a quality product or service to your customers or users.

(e) Communicating well with all your colleagues.

You must now compile a list of the items you need to complete as clearly defined signs that the project has come to an end. You will have agreed these earlier in the project. They could include:

- Ensuring the output of a certain number of products
- Ensuring that the quality of what you deliver reaches the agreed criteria [for example verifying that a computer software system fulfil the required specifications] or undertaking other validating work according to agreed external criteria.

(f) Testing new equipment to make sure it all functions to the required standard.

(g) Training end users, for example, to use the equipment you have installed, or by preparing manuals or running courses.

(h) Identifying any other immediate project work that would be separate from, but associated with, your existing project that is coming to an end.

(i) Determining what, if any, support is needed after the project has come to an end.

(j) Completing final administrative tasks such as final progress reports, especially those concerned with financial resources.

31. BE AWARE OF YOUR TERM'S EMOTIONS

As project leader, you should be aware of the motivations and emotions of members of your team. Your colleagues are probably tired and quite possibly stressed by the long, hard work of the project. They may have had to work through a series of changes during its lifetime, so treat them well! Their levels of energy and enthusiasm may be beginning to go down, so continue to:

(i) Encourage them, constantly affirming the team's commitment to complete the project
(ii) Concentrate their attention on reaching the goal
(iii) Monitor and evaluate their work and your procedures to control schedules and costs
(iv) Remain available for colleagues to bring their concerns to you.

Evaluating the completed project

The project is complete! You've celebrated and are basking in the glory of emails expressing congratulations. Is that is? Is there anything more to be done? Yes: you need to conduct post-project evaluation. This brings together the key points of the project so that you can see that went well, what did not go so well and also, significantly, what lessons you can learn for the future.

Some companies and organizations I have had experience of are so tightly controlled that it seems you are not allowed to be human. Others are at the opposite extreme and are so relaxed that you wonder how any work gets done or at last whether it runs at a profit or even covers costs. The ideal is surely somewhere in between, where colleagues are enabled to fulfil their potential but where procedures and guidelines are in place so that the company knows where it is going, especially as regards financial matters.

Acknowledge failures

In a company or organization with an open culture such as the one just described, mistakes are acceptable, for, as has been remarked, ‘The person who never makes mistakes never made anything. ‘The critical thing here is to learn from your mistakes - neither to ignore them and pretend they did not happen or make them so widely known that blame is attached to an individual for the rest of his or her working life.

If relationships are good [look back at Thursday], then trust and respect will have developed and the important thing – the completion of the project – will be uppermost. Don’t be content with the superficial lesson. Look for the deeper reasons for, say, why a project was delayed:

1. Were adequate monitoring controls in place?
2. Were communications good between colleagues, or were key colleagues not informed about significant decisions?

However, you must ensure that the evaluation is professional: your purpose is not to attach blame to individuals but to be positive and to express a few certain realistic lessons that can be learned and applied in future projects. For example, don’t say: ‘Harry forgot to order the spare parts on time’, but: ‘Checks need to be made in advance that orders for spare parts are submitted two weeks before they are needed.’ Any constructive criticism of an individual’s contributions should be undertaken privately, not in a wider forum.

Recognize success

As well as acknowledging failures, and where you could have undertaken the work better, it is also important to recognize those areas that have gone well, and **identify what you have achieved.** Specifically, list what you have delivered:

a. Solid planning and foundation on which the project was built.
b. Strong support from your project sponsor.
c. The desired output in terms of the products, services, etc. That you have delivered.
d. Outputs measured according to the agreed quality standards.
e. Actual expenditure compared with the original budget.
f. A good return on investment: compare the benefits received from the project against the costs incurred.
g. The actual time taken compared with the original schedule; whether you delivered the outcomes on time or not.
h. The effective management of changes made throughout the project.
i. Robust control procedures in place to track and monitor costs and schedules.
j. Overall, efficient organization so that roles and responsibilities were clearly defined.
k. Good communication between members of the team.
l. Firm commitment by all colleagues to completing the project.
m. A positive outlook, as demonstrated by seeking realistic solutions to the problems encountered.
n. Successfully dealing with the risks encountered during the project.
o. The satisfaction of your customers or users and other stakeholders with the outcomes of your project.

32. WRAPPING UP THE PROJECT

Once you have evaluated the project, acknowledged its successful aspect and recognizing what you might do differently next time, you can make sure that you feed the information back to the team in the following ways:

1. **Acknowledge your team's work**: Before the project team disbands, mark the successful conclusion of your project by some form of celebration that is appropriate to your company or organization. You will want to invite your project sponsor who has believed in the project, your customers or users and other stakeholders. You could, for example, pay for a meal out for all the staff concerned and their partners.

2. **Recognize the achievements of individuals**: Show your personal appreciation to the key individuals, affirming their work and the significant of their participation in the project. I personally like to remember to thank support staff such as secretarial and admin staff; and i gave copies of a long-term reference work that I had worked on to outside companies that provided stationary supplies and courier services.

3. **Plan future meetings:** If the project has been to install new computer systems, you will want to review these after an agreed period to make sure they are working as they should and to resolve any that occur. Future meetings are also the means to build on the [hopefully good] working relationships you have developed during the project and will provide further opportunities for collaboration.

4. **Document lessons learned:** If the costings didn't work out, if communications were weak at certain points, document the reasons. Identify what worked well. Identify what did not go well and consider what measures you will take to avoid making the same mistakes again on future

projects. Such documented identification will be helpful for you in further projects that you will manage in the future.

5. **Write a report for your sponsor:** Produce a final 'end of project' review and report for your project sponsor. Here, you could summarize the progress of the project, examples of good practice, the lessons learned and any recommendations for the future. Ensure that these are written up and keep your own copy, so what you have a record of measures to be taken to avoid making the same mistakes again.

6. **Tying up other 'loose ends':** There will be some relatively insignificant outstanding issues that you will still need to resolve.

7. **Go through the project paperwork:** Now is the time to go through the paperwork you will have amassed during the project. Do not destroy key documents that you might need in the future as evidence of Particular decisions, but you can destroy many working documents.

8. **Continue to learn:** However many projects you may manage, you will always find more effective ways of achieving your goals.

33. THE SAFETY TRIAD

Training, Operations, and Assurance are these three documents to ensure quality and safety in any organisation. These three areas of consideration can be useful to guide the creation of governance documents to ensure quality and safety in any organization's drone operations, whether for a private company or for the armed forces. On one leg of the triangle is Training, on the other leg is Operations, and the base of the triangle is Assurance:

(i) TRAINING: The First Leg of the Safety is Triangle. First, you train your drone pilots to operate in the way you want them to operate We'll cover training in more detail in the section of this guide, but, in brief, training covers listing the types of missions you want your drone pilots to fly, documenting the requirements for those missions, and then having your pilots fly practice missions that simulate the real ones they'll be flying in the field.

(ii) OPERATIONS: The Second Leg of the Safety Triangle. Second, make sure your pilots and any supporting personnel operate in a way consistent with the training you've established. This may require regular inspections, check-lists, and other routine protocol to ensure compliance in operations.

(iii) ASSURANCE: The Third Leg of the Safety Triangle is assurance. Closes the safety loop by checking up on the two legs of the triangle, and ensuring that any changes made to the existing process are reviewed before being incorporated into regular operations. Assurance is important, but unfortunately all too often overlooked.

So what does assurance look like on the ground? Sometimes, there's a good reason operation change—a new mission might call for new protocol, or your team might learn a better way to do something, and so on. When changes take place, the assurance process serves as the check to make sure training is updated to reflect these new missions or tasks. Assurance also checks in on operations. It's common for people to drift away over time from the way they were taught to do something—flying a little higher, a little further away, not following checklists, or maybe just a little after dusk when you don't have.

In these cases, the assurance process, through regular checks, discovers these behaviours and corrects operations back to the original training, and thus back to your established standards. Now that we've covered the safety triad, let's take a look at defining a mission, and considering your mission environment.

34. DEFINING YOUR MISSION AND MISSION ENVIRONMENT

In military aviation, everything starts with the mission, since the mission drives both the training content and the operational execution. And the same should apply for the planning you do when creating your company's drone program.

Will you be taking real estate photos, running a perimeter, doing precision locating, getting a look at a jobsite layout, or something else? Each of these missions has a very different requirements for precision, path, altitude, control, equipment, etc. Only by putting some thought into mission definition will you figure out what your people need to be able to do, and thus how to train them.

Closely related to this is where you're going to be performing these missions. If you're operating out in the middle of nowhere, it's much easier than if you're operating next to an interstate or near obstacles. It's tougher to fly in cramped locations than in open ones, so if your mission requires that kind of flying, you need to make sure your training teaches people how to do it.

Because missions and mission locations can be quite different there isn't one right answer, so "your mileage may vary" when it comes to defining your mission and mission environment.

(i) WHAT ARE FLIGHT OPERATIONS MANAGEMENT TOOLS?

Before we go any further, let's define our terms.

By **flight operations management tools** we mean a single tool that allows drone pilots to:

a. Do airspace research
b. Keep battery logs
c. Keep aircraft maintenance logs
d. Create and store pilot profiles
e. Track insurance
f. Track certification
g. Track registration information

Basically, we're talking about a tool that is a single dashboard for all of the details related to your flight ops, specifically created to store all the flight ops information you need stored, and to provide flight ops information when it comes to airspace research.

Who Should Consider Using a Flight Operations Management Tool? Flight operations management tools aren't necessarily a good fit for everyone. If you're a solopreneur running your own business, and you only have yourself and your own missions to worry about, you probably don't need a flight ops management tool. If you're on a small team of two to three pilots, a flight ops tool is probably a good idea, but may not be crucial for your operations to be a success.

On the other hand, if you work with a team of pilots, either as a service provider or as a unit that's part of a larger organization, be it public or private, then you almost definitely need to be using a flight ops management tool.

The rationale for using a flight operations management tool is simple. If you have a complicated operation with lots of moving parts, you need one place where you can store and track all of your information.

Flight ops tools also help you provide transparency with clients, because they allow you to provide records and other documents related to a mission at the push of a button. On a similar note, it's nice to have a place where all of your records are kept in case you want to do a historic dig into past data to remind yourself about a certain mission, or simply want to refer back to a prior project to inform your current efforts.

Flight Operations Management Tools Below are some of the top flight operations management tools on the market. All of these tools offer free trials, which means you can see what they have to offer from the inside without risking any money. See the last line in each company profile below for the link to register for a free

account. Regarding how to find the right tool for you, the truth is that everyone's needs are unique, and there is no silver bullet or perfect platform. We recommend signing up for free trials, doing small tests, and also reaching out to people in your community to see which tools they've had the most success with. Now without further ado, here are the top flight operations management tools out there

(ii) TRAINING YOUR VISUAL OBSERVER (VO) FOR A DRONE FLIGHT MISSION WHAT IS A VISUAL OBSERVER (VO)?

A Visual Observer (VO) is an optional crew member for a flight mission who serves as a second set of eyes, monitoring the drone in flight in order to support the Remote Pilot in Command (PIC).

Although a VO is not required by the for regular drone missions—missions where the PIC is maintaining a direct visual line of sight with his or her sUAS—having one is certainly useful, and can help lessen the stress of a flight.

(iii) WHY USE A VISUAL OBSERVER

The main reason to use a VO is for greater situational awareness during a flight. While the pilot needs to look back and forth from a screen, to the sky, to his or her hands, the VO can be there maintaining a line of sight with the drone at all times, ensuring that even in those micro-moments where the pilot has to look away the drone is still flying safely.

It's important to emphasize that the role of a VO is not simple. Just having an untrained observer standing nearby watching your drone in flight doesn't cut it. If someone is performing the role of VO, it's important that he or she be properly trained. Just imagine the difference between someone frantically shouting, "Look out, a thing is flying somewhere nearby!" and someone calmly telling you, "Bird, twelve o'clock high, moving slowly away." Now let's dive into the training itself.

(iv) WHAT IS PROJECT EXECUTION?

During the five process groups of the project life cycle, there are multiple objectives and outcomes for each phase. After the project initiation and the planning processes, the execution of the project begins.

Project execution is the third phase of the project life cycle and one of the most vital of the project phases. It is the phase where you will construct your deliverables and present them to your customer and key stakeholders. This is usually the longest phase of the project life cycle and predictably the most demanding.

Project execution's key purpose is to complete the work defined in the project management plan and to meet key project objectives. During this phase a project leader will focus on these key processes:

- Managing people
- Following processes
- Communicating information to all key stakeholders, sponsors and team members

Now that we've covered that, what can program and project managers do to help their organizations close those gaps and add value along the way? The answer is closing the execution gap. There are two pieces to closing the gap:

- Aligning the strategic plan goals and objectives
- Executing in the program and project delivery of outcomes that meet those objectives

Closing that execution gap, also known as the strategy gap, is one of most frustrating challenges facing business leaders today. The execution gap is perceived gap between a company's strategies and expectations and its ability to meet those goals and put ideas into action.

35. EXECUTION GAPS TO WATCH OUT FOR

Six primary gaps that prevent successful project execution:

1. Absence of common understanding
2. Disengaged executive sponsors
3. Misalignment with strategic goals
4. Poor change management
5. Ineffective corporate governance
6. Lacklustre leadership

Shouldn't it be more complicated than this? The reality is that fixing each gap individually is not the solution. The real challenge is finding solutions, developing actions plans and implementing strategy to fix *all* six gaps. According to Williams, it's not rocket science, but understanding how each gap affects your program initiatives is key to the most critical phase of your project – execution.

36. CLOUD SECURITY MANAGEMENT

(i) **Ensure effective governance and compliance:** Most organizations have security, privacy and compliance policies and procedures to protect their IP and assets. In addition to this, organizations should establish a formal governance framework that outlines chains of responsibility, authority and communication. This describes the roles and responsibilities of those involved, how they interact and communicate, and general rules and policies.

(ii) **Audit operation and business processes:** It is important to audit the compliance of IT system vendors that host the applications and data in the cloud. There are three important areas that need to be audited by cloud service customers: internal control environment of a cloud service provider, access to the corporate audit trail, and the cloud service facility's security.

(iii) **Manage people, roles, and identities:** Using the cloud means there will be employees from the cloud service provider that can access the data and applications, as well as employees of the organization that perform operations on the providers system. Organizations must ensure that the provider has processes that govern who has access to customer data and application. The provider must allow the customer to assign and manage roles and authorization for each of their users. The provide must also have a secure system in place to managing the unique identifies for users and services.

(iv) **Proper protection of data:** Data is the core of all IT security concerns for any organization. Cloud computing does not change this concern but brings new challenges because of the nature of cloud computing. The security and protection of data both at rest and in transit needs to be ensured. Interested in learning more about cloud security management? Check out this free whitepaper on how to ensure complete security in the cloud!

(v) **Enforce privacy policies:** Privacy and protection of personal information and data is crucial, especially as many major companies and financial institutions are suffering data breaches. Privacy of personal information is related to personal data that is held by an organization, which could be compromised by negligence or bugs. It is critical that privacy requirements be addresses by the cloud service provider. If not, the organization should consider seeking a different provider or not placing sensitive data in the cloud.

(vi) **Assess security considerations for cloud applications:** Organizations are constantly protecting their business applications from internal and external threats. Application security poses challenges to both the provider and organization, and depending on the type of cloud deployment model (IaaS, PaaS, or SaaS), there are different security policy considerations.

(vii) **Cloud networks and connections are secure:** Cloud service providers must allow legitimate network traffic and block malicious traffic. Unfortunately, cloud service providers will not know what network traffic its customer plan to send and receive. Therefore, organizations and providers must work together to set safety measures, and provide the tools necessary to protect the system.

(viii) **Evaluate security controls and physical infrastructure:** The security of an IT system is also based on the security of the physical infrastructure and facility. Organizations must have assurance from the provider that the appropriate controls are in place. Infrastructure and facilities should be held in secure areas, and protected against external and environmental threats. Further protect access by using a network print security appliance to require user authentication for access to the printer to help eliminate security breaches and reduce printing costs. As organizations migrate their applications and data to the cloud computing, it is critical to maintain the security and privacy protection they had in their traditional IT environment.

37. HOW PROCESS DRONE DATA UNDER THE HOOD

The concept of working on drone data has recently made waves in the geospatial sector, professionals have realized the reliability and cost-effectiveness of data collected using an unmanned aerial vehicle in a safe manner. Land surveyors, in particular, are getting exposed to more options that an unmanned drone is providing them.

Having said all that, a major factor of effectively using data collected by a drone is processing it efficiently. Gathering data using drone might just take a flight but processing it and making it actionable is yet another story.

Drone data is processed using the technique called **Digital Photogrammetry**. The word photogrammetry is derived from: photo — meaning “picture”, and grammetry meaning “measurement”. It is a science of obtaining measurements such as length, area, volume etc from an image.

Processing information collected by an unmanned aerial vehicle is broadly a three-step process:

- Structure from Motion (SFM)
- Multi-View Stereo (MVS)
- Images rectification

These processes can be further understood into following sub-processes.

38. IMAGE FEATURE EXTRACTION

Each drone image has a collection of unique features which differentiate it from other images. These are known as key points. Key points from each image are extracted using automatic computer vision algorithms (SIFT, BRISK, etc.) These features consist of the building's corner, roads, edges, etc.

Generally, images with good texture variation have 40,000+ features. It can be easily understood why photogrammetry performs poor in areas of low texture variation like water bodies, dense forest, sand, sky etc. Key points extraction becomes difficult in texture less surfaces. Image shown below has three scenes Land/Bridge, Sand, Water regions. Each circle represents a unique feature.

Each circle represents a unique feature detected using BRISK detector. The density of features is very high in the leftmost and bridge region since it has a lot of edges, colour changes, etc. Very few features are detected in sand and water regions due to texture less surfaces.

39. FEATURE MATCHING

Extracted features are then searched (in the nearby images) and matching is performed. Using GPS data to search relevant images makes the matching process much faster and accurate. From matched features, fundamental matrix is derived and the relative position between two cameras is estimated. Techniques like Flann is often used to conduct search and match.

40. BUNDLE ADJUSTMENT (BA)

Relative position estimated from the fundamental matrix is generally prone to errors. BA is used to simultaneously refine the 3D coordinates (Lat, Long, Elevation), orientation parameters (Yaw, Pitch, Roll), and the optical characteristics (distortion parameters) of the camera(s) employed to acquire the images. BA is a nonlinear iterative optimization process where the objective function is Mean Reprojection Error (MRE) and parameters are the position, orientation and camera distortion coefficients. BA can be of two types – incremental or global.

41. DEPTH MAP ESTIMATION AND POINT CLOUD GENERATION

Depth value is estimated for every pixel in the image using Multi-View Stereo algorithm. MVS algorithms are able to construct highly detailed 3D models from structured images. So, the output of SFM will act as an input to MVS algorithm. It will output the depth map corresponding to every input image. Individual Depth Map is fused together with the depth map of the neighbouring image to obtain a 3D point. These points are often called as the dense point cloud. It may even consist of greater than 1 crore points for a relatively smaller area.

(i) **Digital Elevation Model (DEM):** 3D Points are triangulated and gridded in 2.5 Dimension space to create 2.5D Digital Elevation Model (Raster). Every pixel in raster has latitude, longitude and elevation information. Interpolation techniques like IDW are often used to do 3D point cloud to 2.5D grid/raster conversion.

(ii) **ORTHOMOSAIC (HD MAPS)**: Orthorectification of each photo is done using DEM. Orthorectification step involves creating a visibility or occlusion map with respect to each image. These maps tell us which pixels are visible or occluded (not visible) from a particular image. Only visible pixels are then selected and colour values are extracted. These orthorectified and occlusion-free photos are mosaiced together to create a large HD Map.

Once the processing is over; Post-processing techniques such as Image Blending, Colour/Contrast adjustment are conducted to remove seam lines present on the boundary of images. Image blending uniforms the color and removes artifacts.

42. WAYS DRONES ARE REVOLUTIONIZING THE CONSTRUCTION INDUSTRY

When we think construction, we think nuts and bolts, two-by-fours and steel beams. Construction has never been overtly forward-thinking or technologically progressive, but the industry is transforming before us, riding the digital wave. Drones and unmanned aerial vehicles (UAVs) have found their way into the construction industry and they are drastically changing the landscape. Using advanced data analytics and imagery captured by drones, companies have strengthened their infrastructure and optimized daily business operations.

The formation of new structures requires a wide range of participants, and to successfully complete a project stakeholder must bring together those moving parts, funnelling those resources into a unified force. By incorporating drones into the equation, the revolving parts have the ability to see through the same lenses from different vantage points, levels, and locations. This data transmits in real-time, allowing instant and seamless collaboration between all stakeholders. With no delay, drones send the data they are collecting from way up high and send it directly back to the operators. Drones have the capability to capture images no human resource could alone, creating a holistic picture of the operation.

We receive revolutionary perspectives, dissolving the dissonance between contractors, architects, and clients, as they all receive a uniform report of the daily happenings. These images have the power to resolve industry pain points that have haunted the construction industry from the dawn of time. Here was examine some of those pain points, discussing how our clients are applying drones in the construction industry to smooth over their current speed bumps.

(i) **Marketing**: High-quality aerial imagery and video footage captured by UAVs can be combined with drone-generated sensor data to create accurate 3D BIM models and renderings. These tools are often used to help community leaders and clients see the viability of a project. Additionally, they can be used

to promote a project to potential investors by helping them visualize the finished development. From a marketing perspective, we get compelling photographic collateral that would entice even the most resistant investors. After all, perception is reality. In giving potential clients a complete picture of how their vision would be executed, they are more likely to commit.

(ii) **Infrastructural Improvements**: Since the inclusion of drones, land surveying has become more efficient and cost-effective. Companies no longer have to rent expensive equipment and hire a dedicated team of contractors to map out an area or property. This makes the planning stage less time-consuming and inexpensive without sacrificing on quality or quantity of data. We can learn how to build more sustainable structures, how to do this faster, and how to reduce resources in the meantime.

(iii) **Remote Monitoring**: Remote monitoring is probably one of the most obvious applications of drones in the construction industry. Supervisors might not necessarily work on-site and clients can be half way across the world from the construction site of the building they are financing. The use of camera drones can give investors and clients an up-close and personal view of the ongoing project while they are off-site, which greatly helps improve customer relationships and makes managing projects remotely easier for project managers.

(iv) **Improving Safety:** Safety is of optimal importance in construction. UAVs allow construction project managers to observe sites in great detail from a remote location without putting workers at risk. The information gathered from these inspections can be used to enhance workflows or develop new site logistics plans that identify areas of interest.

Accidents happen, inevitably. The construction industry operates in high-risk environments, and although there will always be lapses in safety, drones give

us the ability to greatly reduce these lapses by catching safety violations as they happen and delivering that information to supervisors. From there, supervisors can discourage the behaviour from reoccurring and use the evidence however they deem appropriate. By using drones, we can better understand why incidents occur, taking the measures to reduce the number of incidents per capita.

(v) **Insight Gathering**: Drone-generated data allows construction managers to create more accurate 3D BIM models and high-resolution orthomosaic maps that measure true distances and elevation. By overlaying drone-generated point cloud data over the 3D BIM model, project managers can track up-to-date progress on projects, trim costs, and identify mistakes before they can produce costly setbacks. In most cases, drone software can be integrated with in-house programs currently in use, as well as with popular Autodesk design tools like AutoCAD, InfraWorks, Civil 3D, Navisworks, and Revit For construction companies, the return on investment (ROI) is enough of a reason to support the adoption of drones. UAVs cost less to fly and take faster, more accurate measurements than a human survey team. They can be operated remotely to collect additional data on a site as many times as needed while removing any risks associated with sending workers to a potentially dangerous location.

The intelligence generated by drones allows construction project managers to distribute their resources with greater efficiency, increases safety, and reduces overall project costs.

43. STEP BY STEP GUIDE TO COMPLETE YOUR FIRST DRONE MAPPING PROJECT

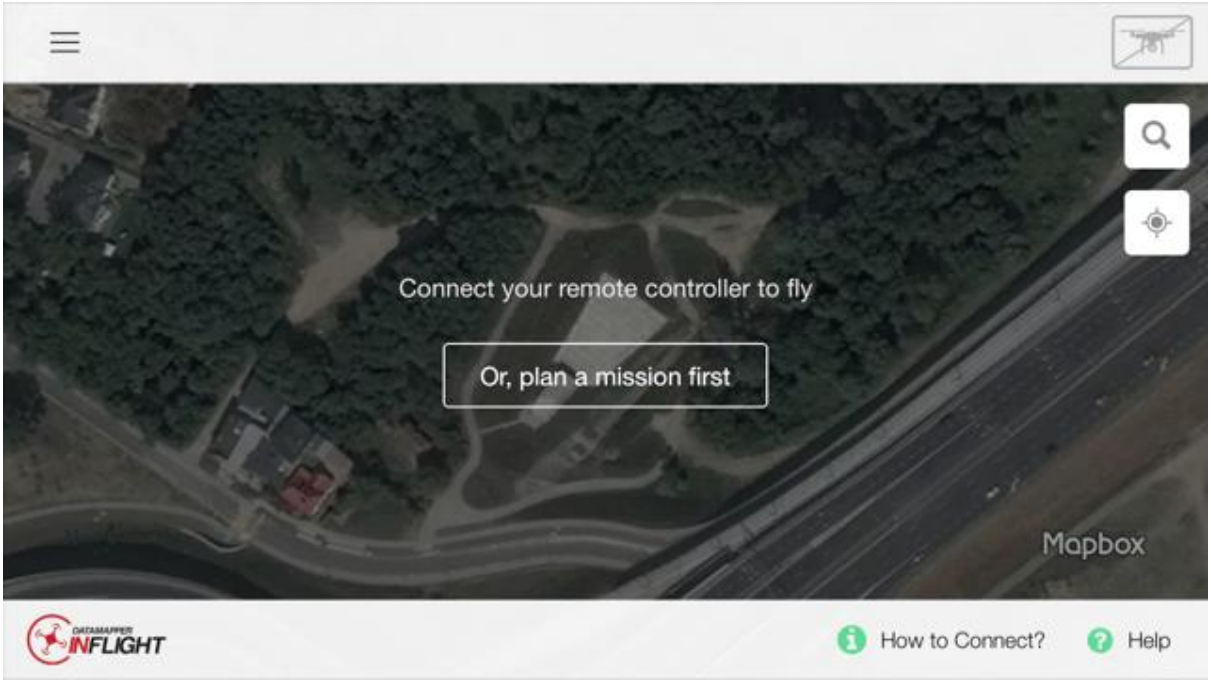
(i) Selecting your drone: The first thing is to select your UAV. The selection of drones on the market is huge but if you search for a drone that will be both: fun to use after hours and good enough for professional applications there is only one choice you should consider – one of DJI's quadcopters (Phantom 3, 4 or Mavic Pro). They are affordable (you can get Phantom 3 for less than $400), they come with a built-in camera, and there are plenty of useful smartphone apps that support DJI's copters.

(ii) Selecting your drone mapping ecosystem: Once you got your DJI drone ready it's time to choose a "mapping solution" that comprises of a smartphone app and a web platform. The app will help to plan your flight properly, and it will take over the control of your DJI drone to automatically complete the survey. After the flight, you will have to transfer the data from your UAV to a computer. To do that you need to take the micro SD card out from your drone, connect it to a computer and upload collected data to a web-based tool that will process the data and let you view and analyze the final output.

The entry level products of a drone survey are orthomosaic, which are essentially stitched together areal images from your drone, transformed to be cartometric, as well as 3D models and point clouds. The basic idea behind it is similar to 3D movies. If you take images of the same object from at least two perspectives, you will get a stereoscopic 3D view. That's why the images from your drone must significantly overlap.

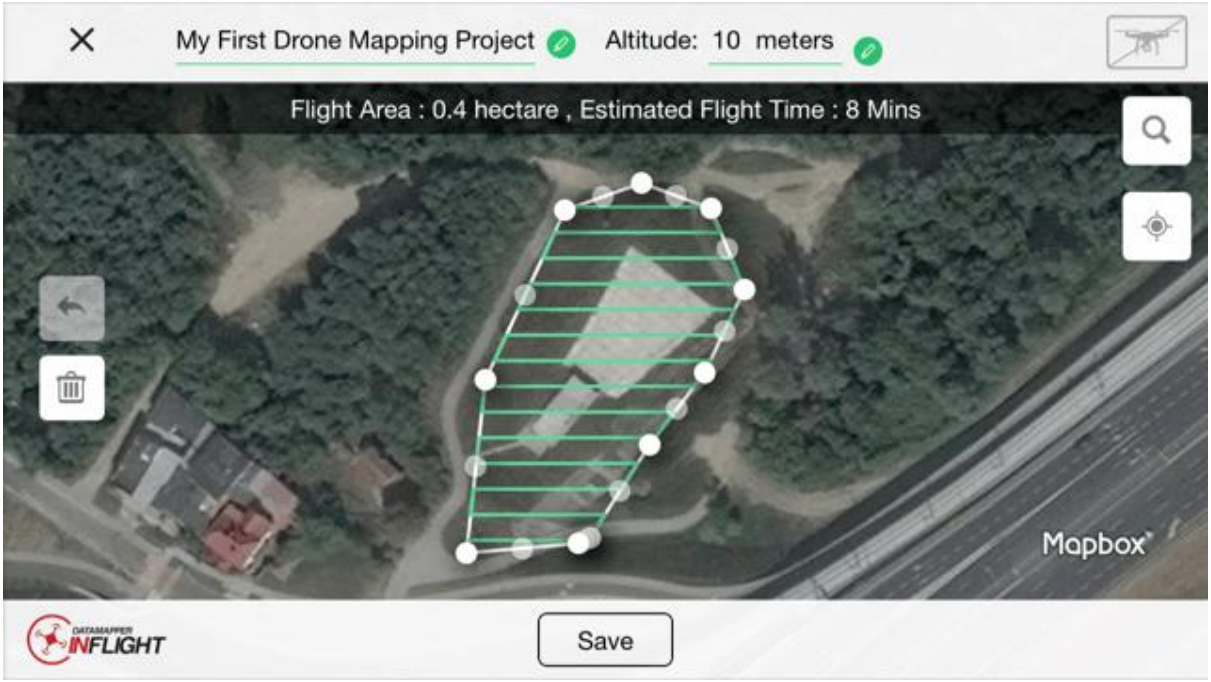
The top three most popular drone mapping platforms out there are Pix4D, Drone Deploy, and Data Mapper. Each of them offers both: the app and the web-based tool.

(iii) Planning your flight: Your main concern when flying a drone should be safety. For your first mapping project select an area without trees and high structures and never fly above people. The area of the project should not be too large and too small. 100x100m (or 300x300ft) should be just fine. Once you've selected the area or a structure you want to map and you've installed Data Mapper on your smartphone, it's time to make use of the app and plan the flight.

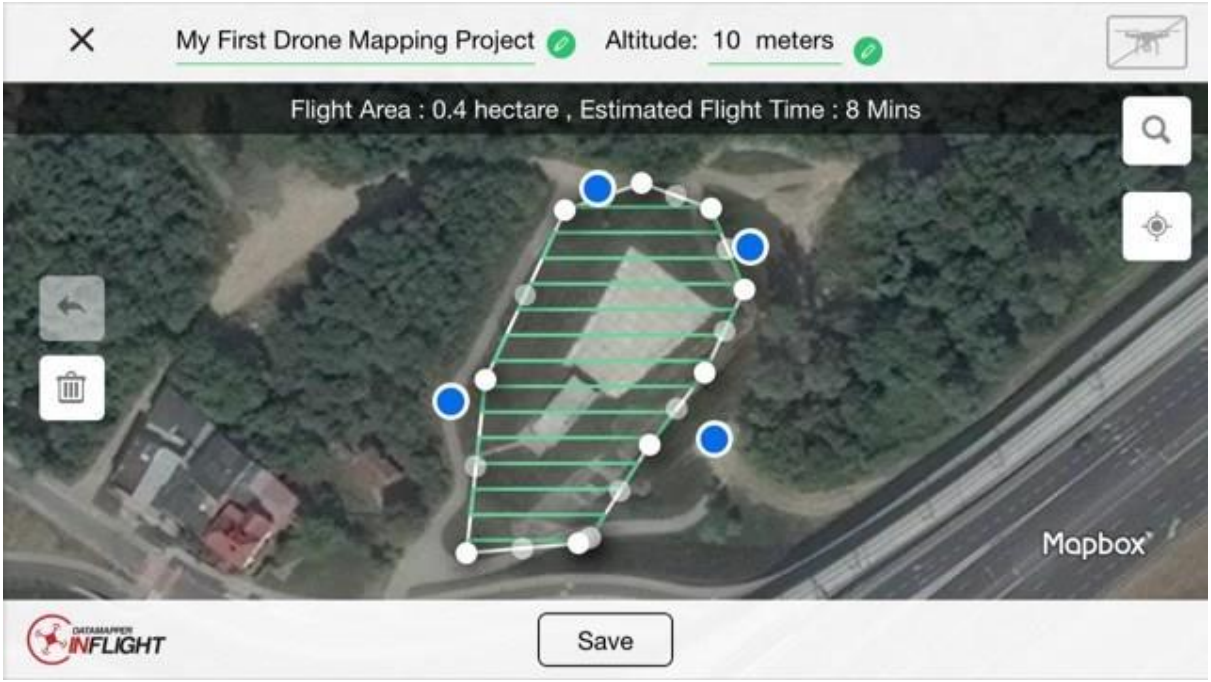


It’s very easy, and you can do it in the field or at home. When you start the app (without any logging), it will ask you to plan your flight.

You need to click on the square on the left side of the screen, and the scope of the flight will pop up on the screen. Now you need to adjust it and draw the area you want to map.

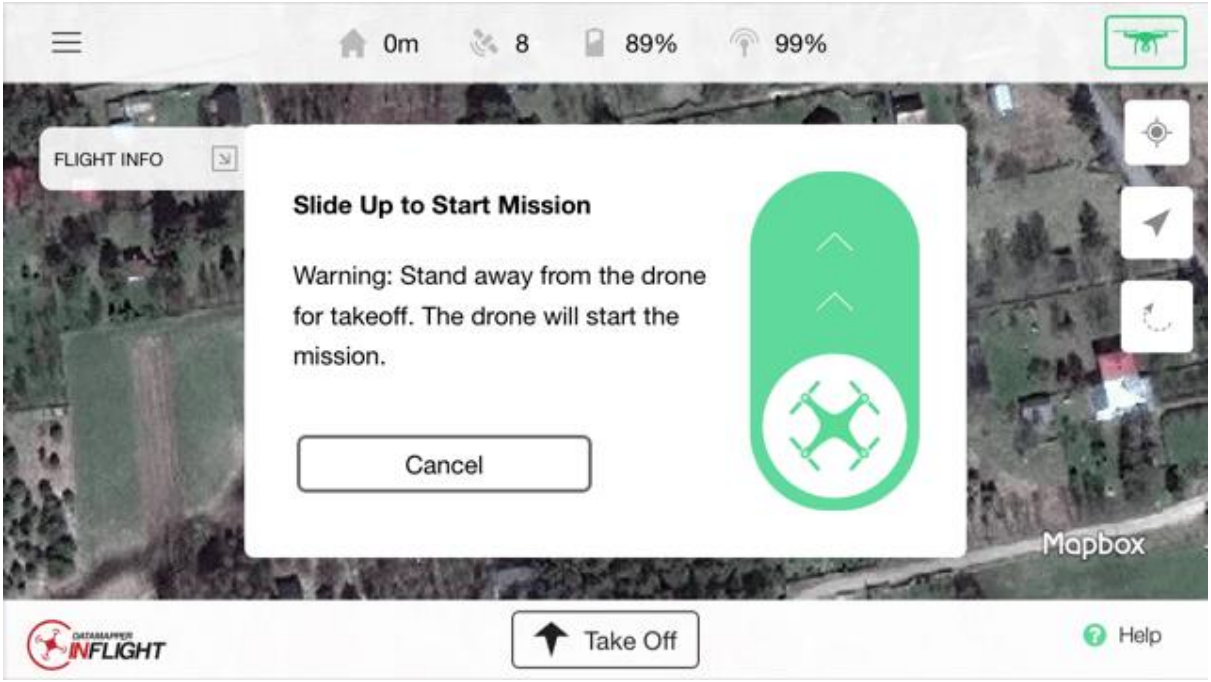


You can do it based on satellite images, but I've noticed that for some locations the images might be old, and it might be difficult to do the planning properly. Error in the planning might cause crushing your drone and causing damage, so you need to be sure that the scope selected in the app is exactly fitting with the area you want to map in the real world. If the satellite imagery is old or there is a risk that by choosing a wrong scope you can crash your UAV there is a trick you can do.



One of the most important parameters is the altitude of your flight. The lower the altitude, the more images your drone has to take to survey chosen area, the longer it will take to complete the survey and the more time and resource consuming the data processing. The altitude will also influence a pixel size. The reasonable approach is to relate the altitude to the size and height of your project area as well as expected accuracy. For a small area of below 100x100m (300x300ft) the flight at the altitude of 10 meters will take almost 10 min and will generate 150 images. Selecting altitude of 30 meters will shorten the flight time to 2 min and decrease the number of images to 50. Knowing that the battery life will last a little over 20 min you can estimate what sort of area you can map on a single charge.

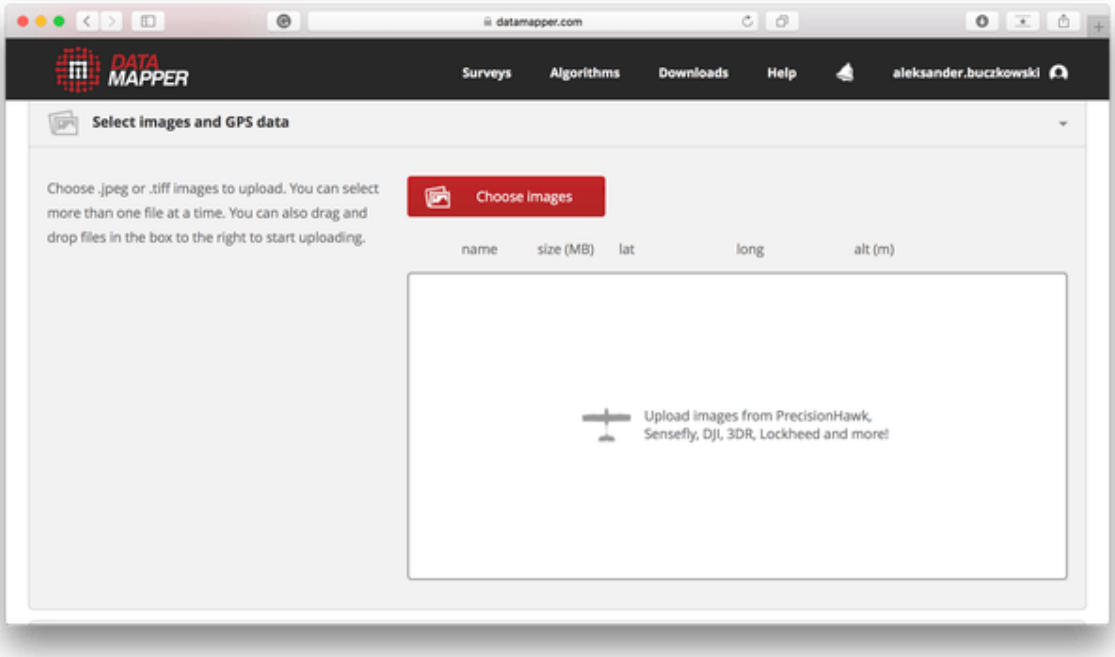
(iv) Take off: To take off you need to connect a smartphone to your DJI drone and simply tap on “Fly”. Confirm and take off.



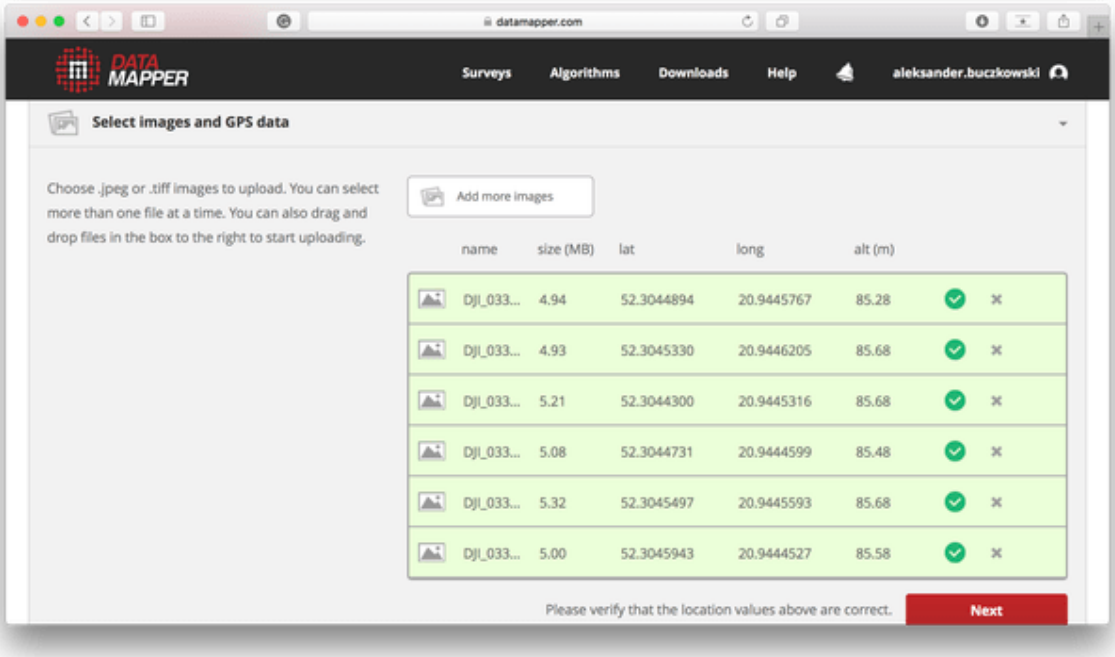
(v) **Review your photos**: If you have an opportunity to review the images still in the field, please do that. Particularly, in the beginning, it will save you a lot of time. During my first flight, I had to go back to the field twice to get the effect I wanted to have. You can also use that time to remove irrelevant images before processing. Pictures of the sky or taken at a strange angle might negatively influence the final effect of the orthomosaic and 3D model.

Remember that DJI doesn't rename your images according to your flight plan, so on the SD card you will see all the images named in order. Sorting out images from the flight your want to process and coping them to a separate folder will help you in the next steps.

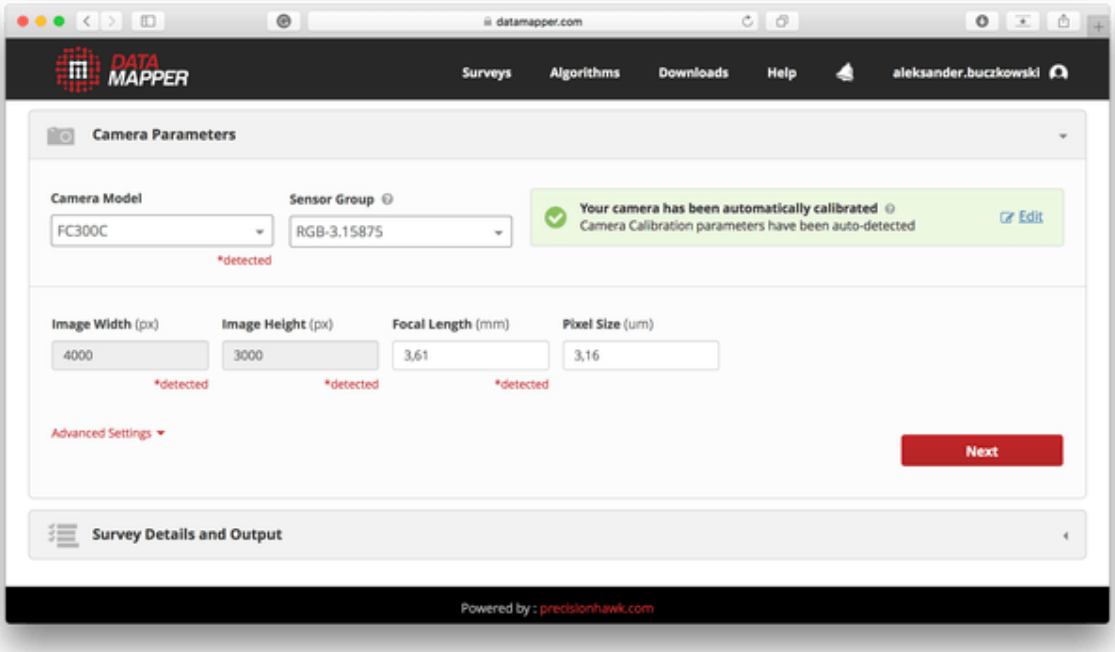
(vi) **Upload your images for processing**: Ok. Now it's time to upload your data. To do that you need to go to datamapper.com and create an account. You don't need to give your credit card details and the first month is for free Go to Surveys and select Upload Survey.



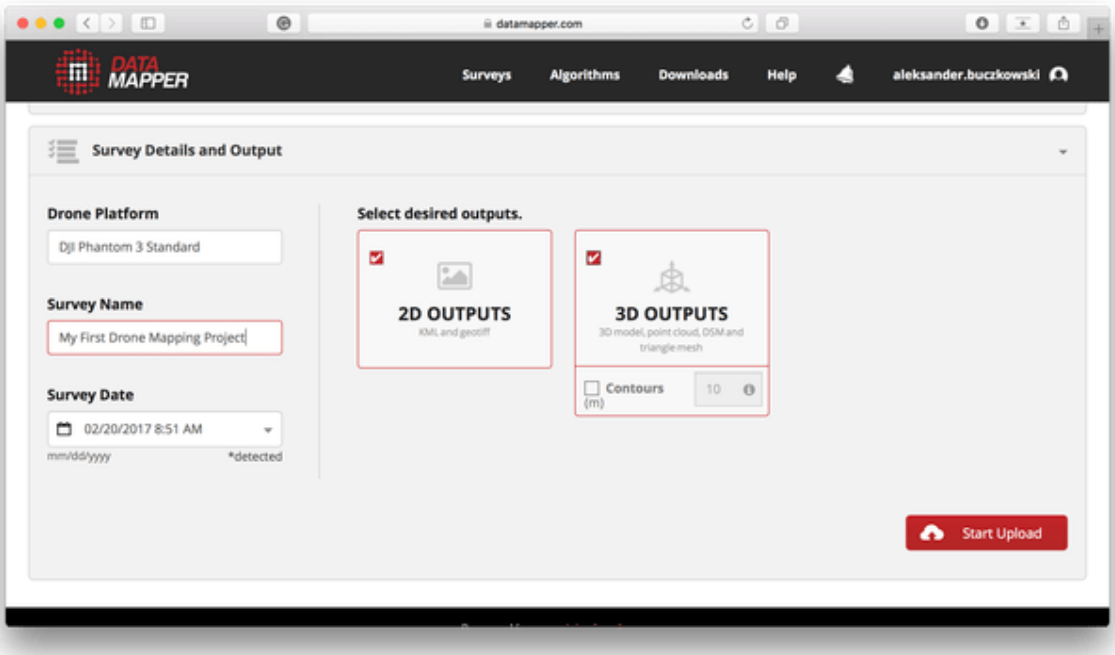
Now select images you want to upload:



you will also be asked to fill in the camera details, but it will be imported automatically from metadata of images:



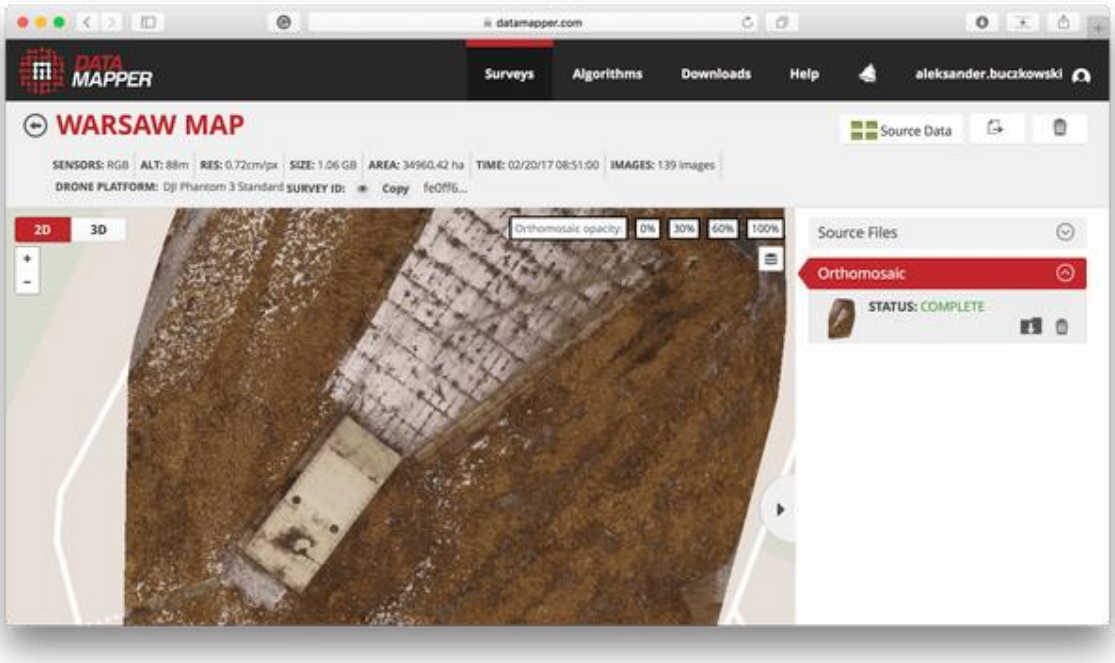
and select the output:



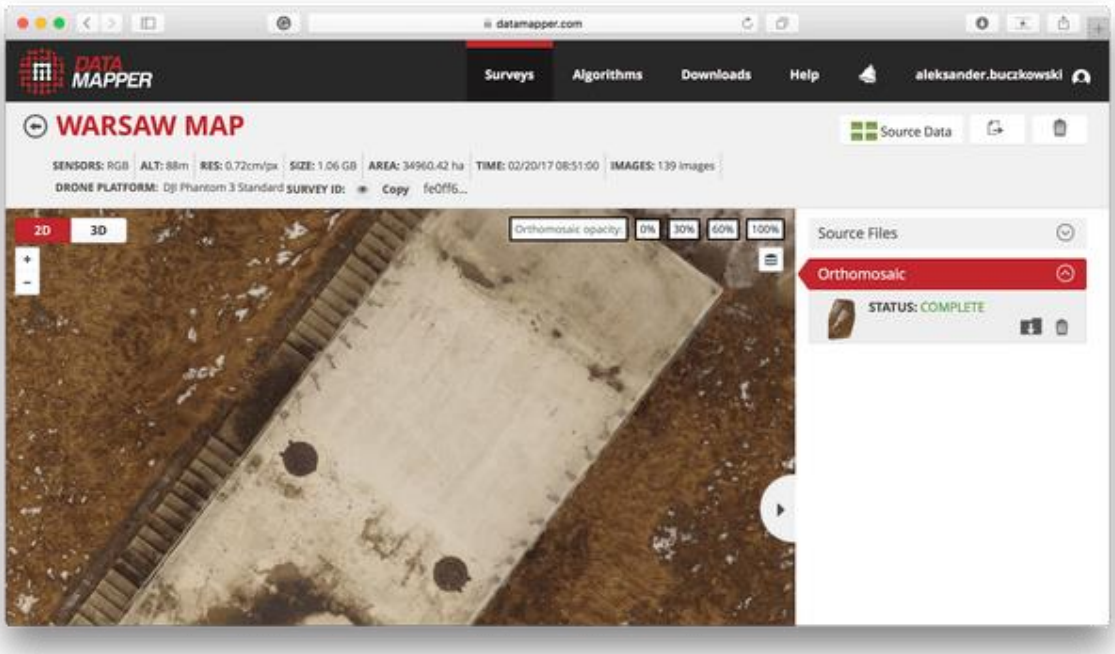
The output can be a flat areal image of the mapped area called “orthomosaic” or a 3D point cloud. Uploading your images might take a couple of minutes, and then the data needs to be processed. The processing status bar is

showed on the website, and the process might take from a few minutes to a couple of hours depending on the scope of your project.

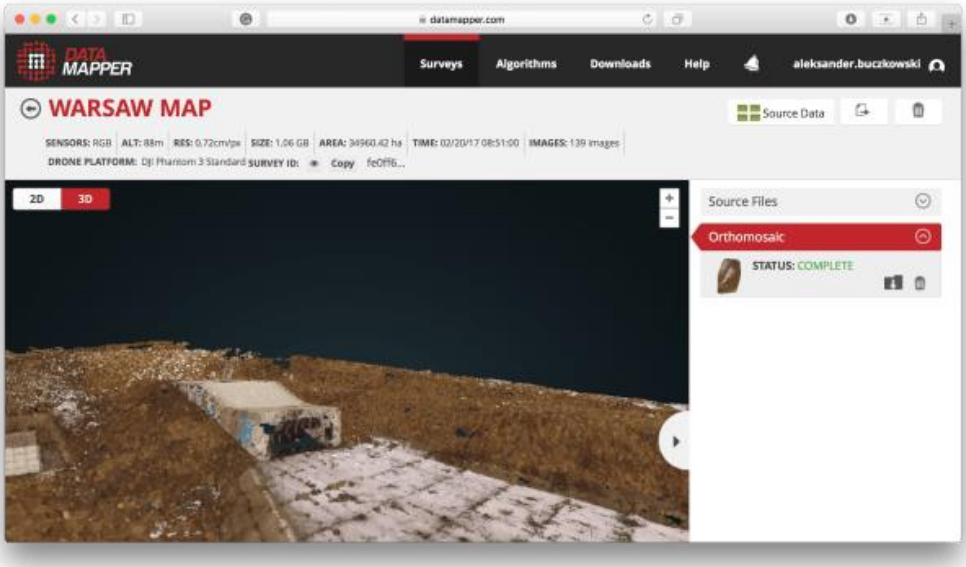
(vii) Enjoy and share your project: Once the processing is completed, you will receive an email, and the last thing to do is to enjoy your first mapping project! Here is the Orth mosaic of the structure I've mapped:



The level of detail is impressive.



You can switch to 3D view and play around with a 3D could point of the surveyed area.



Overall, the basic drone mapping project is not a very complicated process, and you can easily try it yourself! It's a lot of fun, and the effects are amazing. After your first project, you will realize where this whole drone mapping hype comes from.

GOVERNMENT OF INDIA
OFFICE OF THE DIRECTOR GENERAL OF CIVIL AVIATION
TECHNICAL CENTRE, OPP. SAFDARJUNG AIRPORT, NEW DELHI

CIVIL AVIATION REQUIREMENTS
SECTION 3 – AIR TRANSPORT
SERIES X PART I
ISSUE I, DATED 27 AUGUST, 2018 EFFECTIVE: 01st DECEMBER, 2018

F. No. 05-13/2014-AED Vol. IV

Subject: Requirements for Operation of Civil Remotely Piloted Aircraft System (RPAS)

1. INTRODUCTION

1.1 Remotely Piloted Aircraft (RPA), autonomous aircraft and model aircraft are various sub-sets of unmanned aircraft. Unmanned aircraft system (UAS) is an aircraft and its associated elements, which are operated with no pilot on board.

1.2 Remotely piloted aircraft (RPA) is an unmanned aircraft, which is piloted from a remote pilot station. A remotely piloted aircraft, its associated remote pilot station(s), command and control links and any other components forms a Remotely Piloted Aircraft System (RPAS).

1.3 This CAR is issued under the provisions of Rule 15A and Rule 133A of the Aircraft Rules, 1937 and lays down requirements for obtaining Unique Identification Number (UIN), Unmanned Aircraft Operator Permit (UAOP) and other operational requirements for civil Remotely Piloted Aircraft System (RPAS).

2. ACRONYMS &DEFINITIONS

2.1 Acronyms

AAI	**Airports Authority of India**
ADC	**Air Defence Clearance**
ADS-B	**Automatic Dependent Surveillance - Broadcast**
AGL	**Above Ground Level**
AIP	**Aeronautical Information Publication**
ATC	**Air Traffic Control**
ATS	**Air Traffic Service**

ARC	Aviation Research Centre
ARP	Aerodrome Reference Point (published in AIP)
BCAS	Bureau of Civil Aviation Security
CAR	Civil Aviation Requirements
DGCA	Directorate General of Civil Aviation
DGFT	Directorate General of Foreign Trade
DIPP	Department of Industrial Policy & Promotion
FIR	Flight Information Region
FRTOL	Flight Radio Telephone Operator's License
FTO	Flying Training Organization
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IAF	Indian Air Force
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IPC	Indian Penal Code
MHA	Ministry of Home Affairs
MoCA	Ministry of Civil Aviation
MoD	Ministry of Defence
NOTAM	Notice to Airmen
NPNT	No Permission-No Takeoff
NTRO	National Technical Research Organization
PPL	Private Pilot License
RF-ID	Radio Frequency Identification
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System(s)
RPS	Remote Pilot Station(s)
SARPs	Standards and Recommended Practices
SIM	Subscriber Identity Module
TSA	Temporary Segregated Areas
TRA	Temporary Reserved Areas
UA	Unmanned Aircraft
UAOP	Unmanned Aircraft Operator Permit
UAS	Unmanned Aircraft System(s)
UIN	Unique Identification Number
VFR	Visual Flight Rules
VLOS	Visual Line-Of-Sight
VMC	Visual Meteorological Conditions
WPC	Wireless Planning and Coordination Wing, DoT

2.2 Definitions

Command and Control (C2) Link	The data link between the UA and the remote pilot station For the purpose of managing the flight.
Controlled Airspace[1]	Airspace of defined dimensions within which air traffic control service is provided in accordance with the airspace Classification.

Danger Area Airspace of defined dimensions within which activities Dangerous to the flight of aircraft exist at specified times. Such timings are notified through NOTAMs.

Geo-fencing Feature in a software programme that uses the global positioning system or radio frequency identification to define geographical boundaries.

Operator[2] A person, organization or enterprise engaged in or offering to engage in an aircraft operation.

Owner A natural or legal person who owns a remotely piloted aircraft and its remote pilot station.

Payload All components of equipment on board the unmanned aircraft that are not needed for the flight or its control. Its transport aims exclusively to fulfill a specific mission.

Prohibited Area Airspace of defined dimensions, above the land areas or territorial waters of India within which the flights are not permitted at any time under any circumstances.

Remote Pilot A person charged by the operator with duties essential to the operation of a remotely piloted aircraft and who Manipulates the flight controls, as appropriate, during flight time.

Remote Pilot Station (RPS) The component of remotely piloted aircraft system containing the equipment used to pilot the remotely piloted Aircraft.

Remotely Piloted Aircraft (RPA) An unmanned aircraft, which is piloted from a remote pilot station.

Remotely piloted Aircraft System (RPAS) A remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other components, as specified in the type design.

Restricted Area Airspace of defined dimensions above the land areas or Territorial waters of India within which the flight of aircraft is restricted.

RPA observer A trained and competent person designated by the operator who, by visual observation of the remotely piloted aircraft, Assists the remote pilot in the safe conduct of the flight.

Segregated Airspace	**Airspace of specified dimensions allocated for exclusive use to a specific user(s).**
Unmanned Aircraft (UA)	**An aircraft, which is intended to operate with no pilot on board.**
Unmanned Aircraft System (UAS)	**An aircraft and its associated elements, which are operated with no pilot on board.**
Visual line-of-sight (VLOS) operation.	**Operation in which the remote pilot or RPA observer maintains direct unaided visual contact with the remotely Piloted aircraft.**

3. CATEGORIES OF RPA

3.1 Civil RPA is categorized in accordance with Maximum All-Up-Weight (including payload) as indicated below:

i)	**Nano**	**:**	**Less than or equal to 250 grams.**
ii)	**Micro**	**:**	**Greater than 250 grams and less than or equal to 2 kg.**
iii)	**Small**	**:**	**Greater than 2 kg and less than or equal to 25 kg.**
iv)	**Medium**	**:**	**Greater than 25 kg and less than or equal to 150 kg.**
v)	**Large**	**:**	**Greater than 150 kg.**

4. APPLICABILITY

4.1 This CAR is applicable to Civil Remotely Piloted Aircraft Systems, which are remotely Piloted from a Remote Pilot Station.

5. APPLICATION PROCESS

5.1 For RPA imported to India:

a) Any entity intending to import RPAS in India shall obtain Equipment Type Approval (ETA) from WPC Wing, Department of Telecommunication for operating in de-licensed frequency band(s). Such approval shall be valid for a particular make and model.

b) The applicant, other than Nano category, shall apply to DGCA for import clearance as per format given in Annexure-IA. Based upon the import clearance issued by DGCA, DGFT shall issue license for import of RPAS.

c) Upon receipt of import license, the applicant shall apply to DGCA for UIN/ UOAP, as applicable.

5.2 For RPA locally purchased in India:

a) The applicant shall ensure that locally purchased RPAS shall have ETA from WPC Wing, DoT operating in de-licensed frequency band(s). Such approval shall be valid for a particular make and model.

b) The applicant shall submit information as per format given in Annexure-I

c) along with application for issue of UIN / UAOP, as applicable.

5.3 All applications shall be processed on case-to-case basis through "Digital Sky Platform".

6. REQUIREMENTS FOR ISSUE OF UNIQUE IDENTIFICATION NUMBER (UIN)

6.1 Civil RPA except those indicated in Para 6.4 and 6.5 of this CAR, shall require Unique Identification Number (UIN) from DGCA.UIN will be granted where the RPAS is wholly owned either:

a) By a citizen of India; or

b) By the Central Government or any State Government or any company or corporation owned or controlled by either of the said Governments; or

c) By a company or a body corporate provided that:
- **i) it is registered and has its principal place of business within India;**
- **ii) its chairman and at least two-thirds of its directors are citizens of India; and,**
- **iii) its substantial ownership and effective control is vested in Indian nationals;**

d) By a company or corporation registered elsewhere than in India, provided that such company or corporation has leased the RPAS to any organization mentioned in Para 6.1(b) or (c) above.

6.2 Following documents shall be required for issue of UIN:

6.2.1 <u>General</u>:

a) Contact details of owner/ lessee with valid CIN, GSTIN and/ or PAN card.
b) Purpose & base of operation.

6.2.2 <u>Equipment Related</u>:

a) Specification of RPAS.
b) Weight of compatible payload and maximum load carrying capacity of the RPA.
c) RPA Flight Manual/ Manufacturer's Operating Manual (as applicable).
d) Manufacturer's maintenance guidelines for RPA (as applicable).
e) Manufacturer's Certificate of Compliance for NPNT.

6.2.3 <u>Approvals/Clearances</u>:

a) ETA from WPC Wing, Department of Telecommunication for RPA operating in de-licensed frequency band(s), as applicable.
b) Security Clearance from MHA in case of 6.1 (a), (c) & Indian company or corporate leasing RPAS from a company or corporate registered elsewhere

Than in India under 6.1, (d) not earlier than five years from date of application for UIN. However, individuals as indicated in Para 6.1 (a) shall either obtain security clearance from MHA or submit self-attested copies of at least two out of three valid identity proofs viz. Passport, Driving License or Aadhar Card. In case of foreign remote pilots employed by Indian entity as per para 6.1 (b), (c), and (d), DGCA shall forward documents for Security clearance to security agencies in accordance with the procedure being followed for Foreign Aircrew Temporary Authorization (FATA) pilots. The application form for security clearance is given at Annexure II/III of this CAR.

6.3 The applicant shall submit duly filled application (through Digital Sky Platform), as per Annexure IV of this CAR, along with requisite documents indicated in Para 6.2and applicable fee to DGCA. The UIN shall be issued in 02 working days, as per the format given at Annexure-V, provided all the documents are complete.

6.4 RPA in Nano category intended to fly upto 50 feet (15 m) AGL in uncontrolled airspace/ enclosed premises for commercial / recreational / R&D purposes are exempted from obtaining UIN.

6.5 RPAs owned / operated by NTRO, ARC and Central Intelligence Agencies are also exempted from obtaining UIN.

6.6 In case of entity specified under Para 6.1 (d) of this CAR, the Indian organization, who has taken RPAS on lease, shall obtain the UIN.

7. REQUIREMENTS FOR ISSUE OF UNMANNED AIRCRAFT OPERATOR PERMIT (UAOP)

7.1 Civil RPA operators other than those mentioned in Para 7.2 shall require UAOP from DGCA.

7.2 Following entities will not require UAOP:

a) Nano RPA operating below 50 feet (15 m) AGL in uncontrolled airspace / enclosed premises.

b) Micro RPA operating below 200 feet (60 m) AGL in uncontrolled airspace / enclosed premises. However, the user shall intimate to local police office 24 hours prior to conduct of actual operations.

c) **RPA owned and operated by the agencies as indicated in Para 6.5 of this CAR. However, the agency shall intimate local police office and concerned ATS Units prior to conduct of actual operations. .3 Civil RPA operators except entities specified in Para 7.2 shall submit duly filled application through Digital Sky Platform along with requisite fees for issue of UAOP (Application format given in Annexure-VI) to DGCA at least 7 working days prior to actual commencement of operations along with following documents:**

a) SOP as indicated in Para 12 of this CAR;

b) Permission of the land/property owner (only for area used for take-off and landing of RPA);

c) Details of remote pilot(s) along with security clearance from MHA or self-attested copies of at least two out of three valid identity proofs viz. Passport, Driving License or Aadhar Card and copies of training records;

d) Insurance details (as applicable);

e) Security programme as approved by BCAS.

7.4 The UAOP shall be issued by DGCA within 7 working days, as per the format given at Annexure-VII, provided all the documents are complete. A copy of the UAOP shall be provided to MHA, BCAS, IAF, ATS Provider (AAI and MoD), and district administration (Superintendent of Police) for information. In case of UIN issued under Para 6.1 (d) of this CAR, the Indian organization, who has taken RPAS on lease, shall be issued the UAOP.

7.5 Validity of the UAOP shall be for a period of five years from the date of issue.

7.6 The UAOP shall be non-transferrable.

7.7 Renewal of the UAOP shall be subject to fresh security clearance from MHA.

8. SECURITY/ SAFETY REQUIREMENTS

8.1 The operator shall be responsible for the safe custody, security and access control of the RPAS. In case of loss of RPA, the operator shall report immediately to the local police office, BCAS and DGCA.

8.2 The operator of all RPA except Nano RPA shall be responsible for notifying any incident/ accident involving RPA to the Director of Air Safety, DGCA as per Annexure VIII who will further intimate to all concerned agencies.

8.3 In case, the RPA is damaged and cannot be restored to original condition, the same shall be notified to DGCA by the owner/ operator for cancellation of UIN.

8.4 The RPAS operator shall ensure that all security measures as enumerated in the Security Programme (approved by BCAS) are in place before operation of each flight.

8.5 The ground control station (while in use or in store) shall be secured from sabotage or unlawful interference.

8.6 The RPAS (issued with UIN) shall not be sold or disposed-off in any way to any person or firm without permission from DGCA.

8.7 Any changes in the contact details specified in UIN shall be immediately notified to DGCA and all other concerned agencies.

9. REMOTE PILOT TRAINING REQUIREMENTS

9.1 Remote pilot shall have attained 18 years of age, having passed 10th exam in English, and undergone ground/ practical training.

9.2 The ground training shall be obtained at any DGCA approved Flying Training Organization (FTO), and include the following theory subjects:

a) Basic Radio Telephony (RT) techniques including knowledge of radio frequencies.
b) Flight Planning and ATC procedures.
c) Regulations specific to area of operations.
d) Basic knowledge of principles of flight and aerodynamics for fixed wing, rotary wing, and hybrid aircraft.
e) Airspace Structure and Airspace Restrictions with knowledge of No Drone Zones
f) Basic Aviation Meteorology.

9.3 The practical training shall comprise of RPA in flight having live component, and/ or simulated flight training to demonstrate control of RPA throughout its operating conditions, including safe recovery during emergencies and system malfunction. Minimum syllabus and curriculum for training capsule for Remote Pilot is given at Annexure-IX.

9.4 The requirements contained in Para 9.1 through 9.3 of this CAR are not applicable for Nano and Micro category RPA pilots intending to operate in uncontrolled airspace. However, the owner and user shall be fully aware of responsibilities for all aspects of flight safety during such operations.

10. RPAS MAINTENANCE REQUIREMENTS

10.1 Maintenance and repair of RPAS shall be carried out in accordance with the manufacturer's approved procedures, as applicable.

10.2 Maintenance of the ground control equipment shall be carried out in accordance with the manufacturer's recommended inspection and overhaul interval, as applicable.

10.3 The remote pilot/ user shall not fly the RPA unless he/ she is reasonably satisfied that all the control systems of RPA including the radio and Command & Control link are in working condition before the flight.

10.4 The UAOP holder shall maintain records of each RPA flight and make such records available to the DGCA on demand. Such records shall be maintained as per the format given in Annexure-X.

11. EQUIPMENT REQUIREMENTS

11.1 All RPA (except for Nano category intending to operate up to 50 ft (15 m) AGL in uncontrolled airspace/ enclosed premises), shall be equipped with the following serviceable components/ equipment:

a) GNSS for horizontal and vertical position fixing
b) Autonomous Flight Termination System or Return Home (RH) option
c) Flashing anti-collision strobe lights

d) RFID and GSM SIM Card/ NPNT compliant for APP based real time tracking
e) Fire resistant identification plate inscribed with UIN
f) Flight controller with flight data logging capability

11.2 In addition to the equipment required under Para 11.1, all RPA (except Nano and Micro category operating in uncontrolled airspace) intending to operate in controlled airspace up to 400 feet (120 m) AGL shall be equipped with the following additional equipment/capabilities:

a) SSR transponder (Mode 'C' or 'S') or ADS-B OUT equipment
a) Barometric equipment with capability for remote sub-scale setting
b) Geo-fencing capability
c) Detect and Avoid capability

11.3 Remote pilot shall be equipped with communication facilities to establish two way communication with the concerned ATS unit.

11.4 The tracking system of the RPA shall be self-powered and tamper/ spoofing proof to ensure data relay even in the event of RPA accident.

11.5 Indian Air Force shall monitor RPA movements in the country in coordination with Airports Authority of India.

12. OPERATING REQUIREMENTS
12.1 The RPA operator shall prepare Standard Operating Procedures (SOP), which shall contain following procedures according to the provisions contained in relevant sections of AIP-India:

a) Take-off/landing
b) Collision avoidance
c) Noise abatement
d) Flight plan filing
e) Local airspace restriction
f) Right-of-way
g) Communications
h) RPA emergency including loss of C2 link
i) Safe recovery of RPA through controlled airspace in case RPA system failure precludes the ability to remain outside controlled airspace, etc.

12.2 Irrespective of weight category, all RPA operations shall be restricted to day only, within Visual Line of Sight (VLOS), subject to conditions given in Para 12.3.

12.3 RPA operations except those in enclosed premises, shall be conducted only when the following meteorological conditions exist:

a) During daylight (between sunrise and sunset).

b) In Visual Meteorological Conditions (VMC) with a minimum ground visibility of 5 km and cloud ceiling not less than 1500 feet (450 m).

c) Surface winds of not more than 10 knots or as specified by the manufacturer.
d) No precipitation (rain, hail or snow) or thunderstorm activities, or exceeding those specified by the manufacturer.

12.4 The operator [except Nano intending to operate up to 50 ft (15 m) AGL in uncontrolled airspace/ enclosed premises] shall obtain permission before undertaking flight through 'Digital Sky Platform'.

12.5 In addition to the requirement under Para 12.4, all RPA operators [except Nano and Micro category intending to operate up to 50 ft (15 m) AGL and 200 ft (60 m) AGL respectively in uncontrolled airspace/ enclosed premises]are required to file flight plan at least 24 hours before actual operations and obtain following:

a) ATC briefing, Meteorological (MET) briefing, and ATC clearance from the nearest ATC Unit
b) Air Defence Clearance (ADC) from the nearest IAF Unit
c) FIC Number from the Flight Information Centre (FIC) concerned

12.6 Nano and Micro category RPA operators intending to operate beyond 50 ft (15 m) AGL and 200 ft (60 m) AGL respectively in uncontrolled airspace/ enclosed premises, shall not be exempted from the provisions of paragraphs 6 through 12 and 15 of this CAR.
12.7 All RPA operators (except Nano RPA operating below 50 ft), shall inform the concerned local police office in writing prior to commencing the operations.
12.8 RPA Operator shall carry out safety risk assessment [(a) hazard identification, (b) determination of severity and likelihood of hazard on the operation, (c) mitigation measures to reduce the risk identified, and (d) verification of mitigation actions] of the RPA operations including that of launch/ recovery sites. The site (including emergency operation zone and any safety zone for the operations of the RPAS) shall be under the full control of the operator.
12.9 Designated safe areas should be established by the RPA operator for emergency RPA holding and flight terminations.
12.10 The take-off and landing areas should be properly segregated from public access.
12.11 Remote pilots shall prefix RPA call-sign with the word UNMANNED during voice communications between ATC and the remote pilot station. RPA operator shall ensure that no Radio Frequency Interference (RFI) is caused to air traffic operations and air navigation equipment.

12.12 For operations in the controlled airspace, the remote pilot shall establish and maintain contact with ATC prior to entering the controlled airspace.

12.13 All communication between remote pilot station and ATS Unit shall be in

12.14 prescribed ICAO phraseology.

12.14 No person shall act as a remote pilot for more than one RPA operation at a Time.

12.15 If two or more persons are available as remote pilots for a flight, at any given moment, there shall be only one person acting as a remote pilot-in-command.

12.16 RPA operator shall be responsible for ensuring that the RPA is operated safely and remains clear of all manned/ unmanned air traffic, terrain and obstacles.

12.17 RPA shall, at all times, give way to manned aircraft.

12.18 RPA shall not discharge or drop substances unless specially cleared and mentioned in UAOP.

12.19 RPA shall not transport any hazardous material such as explosives or animal or human payload.

12.20 RPA shall not be flown in a manner to cause danger to any person or property.

12.21 RPA operator/ remote pilot shall be liable to ensure that privacy norms of any entity are not compromised in any manner.

12.22 In the event of cancellation of operations, the operator shall notify the same to all appropriate authorities immediately.

13. OPERATING RESTRICTIONS

13.1 No RPA shall be flown:

a) Within a distance of 5 km from the perimeter of airports at Mumbai, Delhi, Chennai, Kolkata, Bangalore and Hyderabad;

b) Within a distance of 3 km from the perimeter of any civil, private or defence airports, other than those mentioned in Para 13.1(a);

c) Above the Obstacle Limitation Surfaces (OLS) or PANS-OPS surfaces, whichever is lower, of an operational aerodrome, specified in Ministry of Civil Aviation (Height Restrictions for Safeguarding of Aircraft Operations) Rules, 2015 notified through Gazette of India notification GSR751(E) as amended from time to time;

d) Within permanent or temporary Prohibited, Restricted and Danger Areas including TRA, and TSA, as notified in AIP;

e) Within 25km from international border which includes Line of Control (LoC), Line of Actual Control (LAC) and Actual Ground Position Line (AGPL);

f) Beyond 500 m (horizontal) into sea from coast line provided the location of ground station is on fixed platform over land;

g) Within 3 km from perimeter of military installations/ facilities/ where military activities/ exercises are being carried out unless clearance is obtained from the local military installation/facility;

h) Within 5 km radius from Vijay Chowk in Delhi. However, this is subject to any additional conditions/ restrictions imposed by local law enforcement agencies/ authorities in view of the security.

i) Within 2 km from perimeter of strategic locations/ vital installations notified by Ministry of Home Affairs unless clearance is obtained from MHA;

j) Within 3 km from radius of State Secretariat Complex in State Capitals;

k) From a mobile platform such as a moving vehicle, ship or aircraft;

l) Over eco-sensitive zones around National Parks and Wildlife Sanctuaries notified by Ministry of Environment, Forests and Climate Change without prior permission.

13.2 No RPA shall carry out aerial photography/remote sensing survey over the areas specified in Para 13.1 of this CAR. However, DGCA may authorize such operations on case-to-case basis subject to approval of MoD. In such a case, application shall be submitted to Director Regulations & Information, DGCA (seven copies) in the prescribed format as indicated at Annexure-XI.

14. GENERAL REQUIREMENTS

14.1 Operation of RPA beyond the conditions specified in Para 12.2 and 12.3 of this CAR may be authorized by DGCA on case-to-case basis subject to adequate justification provided by the applicant for safe conduct of RPAS operations.

14.2 To encourage new technology, Indian Organizations/ Institutions involved in R & D related activity of RPAS shall use the test sites as indicated in Annexure-XII for testing/ demonstration purpose.

14.3 The organizations mentioned at Para 14.2, may alternatively utilize unused airstrips or Government educational institutions campus, provided adequate safety precautions are in place.

14.4 It shall be the responsibility of operators/ R&D Institutions, to ensure that no manned or unmanned aircraft is flying during such operations in the intended test area.

14.5 Roles & responsibilities of Govt. Stakeholders on various aspects of operation of civil remotely piloted aircraft system are given at Annexure-XIII.

15. MINIMUM STANDARDS FOR MANUFACTURING OF RPAS (BOTH INDIAN & FOREIGN)

15.1 The minimum standards for manufacturing of Small and above categories of RPAS are given in Annexure-XIV.

15.2 For Nano and micro categories of RPAS, the minimum standards for manufacturing as envisaged by designer/OEM, shall be considered.

15.3 For all categories of RPAS except Nano, the manufacturer shall provide a Certificate of Compliance along with NPNT compliance to DGCA.

16. LEGAL OBLIGATIONS

16.1 UIN and/ or UAOP issued by DGCA shall not:

a) Confer on RPAS operator any right against the owner or resident of any land or building or over which the operations are conducted, or prejudice in any way the rights and remedies which a person may have in respect of any injury to persons or damage to property caused directly or indirectly by the RPA.

b) Absolve the operator/ remote pilot from compliance with any other regulatory requirement, which may exist under the State or local law.

17. INSURANCE

17.1 All civil RPA operators shall have insurance with the liability that they might incur for any damage to third party resulting from the accident/incident.

18. ENFORCEMENT ACTION

18.1 In case of violation of provisions of this CAR/ approved operating conditions, the UIN/ UAOP issued by DGCA shall be suspended/ cancelled.

18.2 Breach of compliance to any of the requirements and falsification of records/ documents shall attract penal action including imposition of penalties as per applicable IPCs (such as 287, 336, 337, 338 or any relevant section of IPC).

18.3 Necessary actions shall be taken as per relevant sections of the Aircraft Act 1934 / the Aircraft Rules 1937 or any statutory provisions.

(B. S. Bhullar)
Director General of Civil Aviation

Annexure-IA

APPLICATION FOR IMPORT OF REMOTELY PILOTED AIRCRAFT

1. Name of Applicant/ Owner/ Operator:
   (In case of Company/ Corporation,
   Provide names of owners/directors and their nationalities)
2. Contact details (Address, E-mail ID, Phone No.):
3. Nationality:
4. Category: Existing UAOP holder/ UAOP applicant/ Without UAOP
5. Fleet strength:

No.	RPA type	UIN	Mode of acquisition (Owner / lease)

6. Details of RPA proposed to be imported/ acquired:

Items	RPA details
Name and address of manufacturer	
Nationality	
Model No.	
Serial Number	
Date and Year of Manufacture	
Fixed Wing/ Rotary Wing	
New/ Used	
Maximum all-up-weight	
Maximum height attainable	
Payload details	

7. Mode of import (Lease/Outright Purchase):

Outright Purchase	Lease		
Name & Address of the owner (name of manufacturer in case of new RPA)	Name & Address of the owner	Name & Address of the Lessor	Name & Address of the Lessee

8. Purpose of Operation of RPA:

9. Proposed base of operation:

10. Copy of security clearance:

UNDERTAKING

1. The RPA shall be used only for the purpose for which it is being imported/ locally purchased and meets the regulations contained in CAR Section 3, Series X, Part I.

2. RPA shall be maintained and operated in accordance with the regulation specified by DGCA from time to time and there is no binding or limitation of any kind in this regard in the lease agreement for the acquisition of the RPAS.

3. Certified that the information given above is correct.

Date:

(Signature of the applicant)
Name :
Designation:

Note: Strikeout whichever is not applicable.

PROFORMA FOR INFORMATION FOR LOCALLY PURCHASED REMOTELY PILOTED AIRCRAFT

1. Name of Applicant/ Owner/ Operator:
   (In case of Company/ Corporation,
   Provide names of owners/ directors and their nationalities)
2. Contact details (Address, E-mail ID, Phone No.):
3. Nationality:
4. Category: Existing UAOP holder/ UAOP applicant/ Without UAOP
5. Fleet strength:

No.	RPA type	UIN	Mode of acquisition (Owner / lease)

6. Details of RPA proposed to be imported/ acquired:

Items	RPA details
Name and address of manufacturer	
Nationality	
Model No.	
Serial Number	
Date and Year of Manufacture	
Fixed Wing/ Rotary Wing	
New/ Used	
Maximum all-up-weight	
Maximum height attainable	
Payload details	

7. Mode of acquisition (Lease/ Outright Purchase):

Outright Purchase	Lease		
Name & Address of the owner (name of manufacturer in case of new RPA)	Name & Address of the owner	Name & Address of the Lessor	Name & Address of the Lessee

8. Purpose of Operation of RPA:

9. Proposed base of operation:

10. Copy of security clearance:

UNDERTAKING

1. The RPA shall be used only for the purpose for which it is being imported/ locally purchased and meets the regulations contained in CAR Section 3, Series X, Part I.

2. RPA shall be maintained and operated in accordance with the regulation specified by DGCA from time to time and there is no binding or limitation of any kind in this regard in the lease agreement for the acquisition of the RPAS.

3. Certified that the information given above is correct.

Date:

(Signature of the applicant)
Name :
Designation :

Note:
1. **Strikeout whichever is not applicable.**
2. **Filled proforma to be submitted along with duly filled application for UIN.**

Annexure-II

APPLICATION PROFORMA FOR SECURITY CLEARANCE

I. Details of Company/ Firm (Indian/ Foreign)

No.	Full Name of the company and its foreign collaborator, if any	Date of registration of company	Address of Head Office, Regional Offices & Registered Office	Previous name of company, if any	Details of earlier approvals, if any (Ref. No. & date)

II. Details of Directors

No.	Full Name of Board of Directors	Present Position held with date (since when)	Date of Birth	Parentage	Present & Permanent Address	Nationality	Passport No. and Date of Issue	Contact Address & Tel. No.

III. Details of Shareholders of Applicant Company (All firms/ companies/ entities/ individuals having shareholding more than 10%)

No.	Full Name	Parentage Father/ Mother	Date of Birth	Permanent Address	Present Address	Present Position held in the company, if any	Nationality (if holding dual nationality, both must be clearly mentioned)	% of shares held in the comp-any

IV. Details of criminal cases, if any, against the Company/ Director(s) as per Annexure IIA

Date:

(Signature of the applicant)
Name :
Designation :

SELF-DECLARATION FOR COMPANY AND DIRECTOR(S) FOR WHOM SECURITY CLEARANCE IS SOUGHT

a)	**Name & address and registration no. of the company**	
b)	**Name & address of owners, promoters and directors of the company** **1.** **2.** **3.** **4.**	
c)	**Is the company owners, promoters or directors listed above have** **4. Preventive detention proceedings (PSA/ NSA etc.)** **5. Criminal proceedings**	 **Yes/No** **Yes/No**
d)	**If Yes, please provide following details** **1. Detention/ Case/ FIR/ Warrant Number** **2. Police Station/ District/ Agency** **3. Section of law** **4. Name & place of the court**	
e)	**The above mentioned details are in respect of both in India and in foreign country, if any.**	

Note: The above self-declaration is required to be filled and signed by the authorized signatory of the company.

Date:

(Signature of the applicant)
Name :
Designation :

APPLICATION PROFORMA FOR SECURITY CLEARENCE (INDIVIDUALS)

1. (a) Name of Applicant in full (in block letters)
Surname Name Aliases, if any

(b) Parentage:
Surname Name Aliases, if any

2. Present address in full, including nearest Police Station:

3. (a) Permanent address in full, including nearest Police Station:

(b) If originally a resident of a country other than India, address in that country and the date of migration to India.

4. Nationality:

5. Date and place of birth, with full address:

6. Profession/ occupation after the age of 18 years:

7. Particulars of places, with full address, where the applicant has resided for more than a year during the preceding five years:

8. Has the applicant ever been arrested, prosecuted, kept under detention, or convicted by a court? Give details:

Certified that the information furnished in this proforma is correct and complete to the best of my knowledge and belief. I am aware that furnishing of wrong information or suppression of factual or material information will dis-entitle me from grant of the license/ permit.

Date:

(Signature of the applicant)
Name :
Designation :

Annexure-IV

APPLICATION FOR UNIQUE IDENTIFICATION NUMBER (UIN) OF REMOTELY PILOTED AIRCRAFT (RPA) - (USE ONE APPLICATION PER RPA)

Section A: Particulars of Applicant/Owner/Operator of RPA

1. Copy of import permission / filled proforma for information of local acquisition
2. Valid CIN, GSTIN and PAN Card
3. Copy of security clearance from MHA or self-attested copies of at least two out of three valid identity proofs viz. Passport, Driving License or Aadhar Card (in case of individual/Indian remote pilot)
4. Copy of Permission/ license from WPC Wing, Department of Telecommunication for usage of licensed frequencies used in RPA. (as applicable)
5. Copy of ETA from WPC Wing, Department of Telecommunication for RPA operating in de-licensed frequency band(s) (as applicable)
6. Details of fees paid *

Section B: Specification of Remotely Piloted Aircraft

7. Name and address of manufacturer
8. Model No.
9. Serial Number
10. Date and Year of Manufacture
11. Fixed Wing/ Rotary Wing
12. New/Used
13. Maximum all-up-weight (including Payload)
14. Category of RPA
15. Details of compatible payload
16. Place &region of operation as per AAI FIR
17. Purpose of operation
18. Engine/Motor : a) Type, b) Power Rating and c) Number of Engines/Motors
19. Total fuel capacity (kg)/ Battery capacity (mAh)
20. Propeller details
21. Overall dimensions (l x b x h)
22. Maximum Endurance
23. Maximum Range
24. Maximum Speed
25. Maximum Height attainable
26. Maximum Height of operations required
27. GNSS (GPS) for horizontal and vertical position fixing
28. Autonomous Flight Termination System or Return Home (RH) option
29. Flashing anti-collision strobe lights
30. RFID and GSM SIM Card/ NPNT compliance for APP based real time tracking
31. Fire resistant identification plate inscribed with UIN
32. Flight Controller with flight data logging capability
33. Particulars of previous or existing UIN, if applicable
34. Copy of Remotely Piloted Aircraft Flight Manual/ Manufacturer's Operating Manual (as applicable)
35. Copy of Manufacturer's Maintenance guidelines (as applicable)

36. History of incidents/accidents (if any) along with nature and extent of damage sustained by the RPA and details of any repairs carried out.

37. Undertaking:

I hereby declare that the above particulars are true in every respect and that nothing has been concealed or withheld by me. I have studied the relevant regulations issued by DGCA from time to time and shall abide by them.

Date:

(Signature of the applicant)
Name :
Designation :

*** Note: The fee for issue of unique identification number for a remotely piloted aircraft shall be ₹1000/- only.**

FORMAT FOR ISSUE OF UNIQUE IDENTIFICATION NUMBER

DIRECTORATE GENERAL OF CIVIL AVIATION
OPP. SAFDARJUNG AIRPORT, NEW DELHI110003,

Unique Identification Number	**Manufacturer and Manufacturer's designation of Remotely Piloted Aircraft System**	**Remotely Piloted Aircraft Model No.**
		Max. All-up-weight (kg).
U-XX-XXXX		**Category**
		Type of Aircraft **Fixed Wing/ Rotary Wing**
Name of owner		
Address of owner		
E-mail ID & Contact No. of Owner		
Name of Operator		
Address of Operator	**INDIA**	

UNIQUE IDENTIFICATION NUMBER

E-mail ID & Contact No. of Operator

It is hereby certified that the above mentioned Remotely Piloted Aircraft System has been duly entered in the Indian Civil Unmanned Aircraft database.

Annexure-VI

APPLICATION FOR ISSUE/ RENEWAL OF UNMANNED AIRCRAFT OPERATOR PERMIT (UAOP)

1. **UIN No./ Existing UAOP Number (If applicable)**
2. **Details of Remote pilot(s) and training records**
3. **Security programme approved by BCAS**
4. **Permission of land/ property owner (area used for take-off and landing of RPA)**
5. **Insurance details (as applicable)**
6. **Standard Operating Procedures**
7. **Details of fees paid***

8. **Undertaking:**

   (a) I hereby declare that the above particulars are true in every respect and that nothing has been concealed or withheld by me. I have studied the relevant regulations issued by DGCA from time to time and shall abide by them.

   (b) I shall keep RPA Flight Manual / Manufacturer's Operating Manual (as applicable) up to date at all times. I shall specify procedures to be followed by remote pilots and other relevant persons to ensure safety of RPA operations and shall produce the same as and when demanded by DGCA.

   (c) I shall maintain RPAS as per maintenance system established by manufacturer and details of the same shall be kept up to date at all times and shall produce relevant records of maintenance as and when demanded by DGCA.

Date:

(Signature of the applicant)
Name :
Designation :

***Note:**
1. Fees for issue of Permit is ₹25,000/-
2. Fees for renewal of Permit is ₹10,000/-

FORMAT FOR ISSUE OF UNMANNED AIRCRAFT OPERATOR PERMIT

DIRECTORATE GENERAL OF CIVIL AVIATION
OPP. SAFDARJUNG AIRPORT,
NEW DELHI-110003, INDIA

UNMANNED AIRCRAFT OPERATOR PERMIT

Unmanned Aircraft Operator Permit	
Name of operator	
Address of operator	
E-mail & Contact No. of operator	

This certificate certifies that <operator name> is authorized to perform RPA operations as defined in the attached operations specifications and in accordance with the regulations prescribed in CAR Section 3, Series X, Part I.

Date of Issue		**Signature**	
Date of Expiry		**Name**	
Place of Issue		**Designation with Seal**	

DIRECTORATE GENERAL OF CIVIL AVIATION
OPP. SAFDARJUNG AIRPORT,
NEW DELHI-110003, INDIA

RPAS OPERATIONS SPECIFICATIONS	
UIN Number	
Type of operations	
Area of base of operations	
Approved personnel for RPAS operation	
Operating limitations	
1. Maximum Endurance	
2. Maximum Ceiling	
3. Compatible Payloads (with weight), etc.	
Date of Issue	

Signatures

Annexure-VIII

OCCURRENCE REPORT FOR REMOTELY PILOTED AIRCRAFT (RPA)

Date of occurrence	
Time of occurrence	
Place of occurrence	
Latitude/Longitude	
Phase of flight	**Take-off/ cruise/ landing/ hover**
Type of operation	**Commercial/ recreational/ survey/ photography/ R&D/ Other (please specify)**
Colour of RPA	
Category of RPA	**Nano/ Micro/ Small/ Medium/ Large**
Make/Model No.	
UIN No.	
Year of manufacture	
Damage details	**RPA/ property**
Details of injury to persons	
Name of operator/company	
Details of remote pilot	
UAOP No.	
Brief description of occurrence	
Was RPA flying near aircraft?	
If yes, provide approx. distance	
Was RPA flying near airport/ helipad?	
If yes, provide approx. distance	
Was RPA last seen near prohibited/ restricted areas?	**Please specify**

No. Subjects

Theory Classes

1. **Regulations of DGCA**
2. **Basic Principles of Flight**
3. **ATC Procedures & Radio Telephony**
4. **Fixed wing Operations/Aerodynamics**
5. **Multi rotor Operations/Aerodynamics**
6. **Weather & Meteorology**
7. **Drone equipment and maintenance**
8. **Emergency Identification & handling**
9. **Payload installation & utilization**
10. **Image/Video interpretation**
11. **Final Test Theory**

Practical Training

1. **Flight Simulator training**
2. **Practical lessons in Lab**
3. **Practical flying lessons**

Total Training

Annexure-IX

BLOCK SYLLABUS FOR TRAINING CAPSULE - 05 WORKING DAYS

CIVIL AVIATION REQUIREMENTS **SECTION 3 – AIR TRANSPORT**

SERIES X PART I **27TH AUGUST, 2018**

DETAILED CURRICULUM FOR TRAINING CAPSULE - 05 WORKING DAYS

Day 01:

Regulations of DGCA , Civil Aviation Requirements (01 Class)

- **Classification**
- **Basic Air Regulations**
- **Salient points**
- **Do's and Don'ts**

Basic principles of flight (01 Class)

- **Fundamentals of flight**
- **Aerodynamics**
- **Take-off, flight, and landing**
- **Manoeuvres, turns and circuit pattern**

ATC procedures & Radio Telephony (01 Class)

- **Understanding ATC operations**
- **Airspace Structure and Airspace Restrictions with knowledge of No Drone Zones**
- **Communicating with ATC including Position and Altitude Reporting**
- **Flight Planning Procedures**
- **Collision avoidance**
- **Radio Telephony (RT) techniques**
- **Standard radio terminology and RT Phraseology**
- **Practice Session in Radio Communication**

Fixed wing operations and aerodynamics (01 Class)

- **Types of fixed wing drones, make, parts and terminology**
- **Operation and manoeuvres of fixed wing drones**
- **Applications and operations**
- **Advantages/disadvantages over multi rotor**

drones Multi rotor introduction (01 Class)

- **Basic drone terminology**
- **Types of drones, material used and size of drones**
- **Motors and propellers**
- **Electronic Speed Controller (ESC), flight controllers**
- **Operation and Applications of drones**

- **Advantages/disadvantages over multi rotor drones Weather and meteorology (01 Class)**
- **The standard atmosphere**
- **Measuring air pressure**
- **Heat and temperature**
- **Wind**
- **Moisture, cloud formation**
- **Met Terminal Aviation Routine Weather Report (METAR)**

Drone equipment maintenance (01 Class)

- **Maintenance of drone, flight control box, ground station**
- **Maintenance of ground equipment, batteries and payloads**
- **Scheduled servicing**
- **Repair of equipment**
- **Fault finding and rectification**

<u>Day 02</u>:

Emergency identification and handling (01 Class)

- **In flight emergencies**
- **Loss of link**
- **Fly-aways(Straying)**
- **Loss of power**
- **Control surface failures**

Payload, installation and utilization (01 Class)

- **Types of payloads**
- **Parts of payloads**
- **Installation**
- **Features of payloads**
- **Utilization**

Image and video interpretation (01 Class)

- **Principles of observation**
- **Interpretation of image/video**
- **Analysis**

Final test - Theory (40 min)

Introduction to flight simulator (01 Class)

- **Basic operating features of simulator**
- **How to select different aircrafts and aerodromes**

Flight simulator training (02 Classes)

- **Pre-flight checks and start-up**
- **Preparation cum coordination for flight**
- **Take-off and flight stage**
- **Approach and landing**
- **After flight checks**

Day 03:

Flight simulator training (05 Classes)

- **Pre-flight checks and start-up**
- **Preparation cum coordination for flight**
- **Take-off and flight stage**
- **Approach and landing**
- **After flight checks**

Practical lessons in Lab (01 Class)

- **Assembling of drone**
- **De-assembling**
- **Integration of sub-sections/ modules**
- **Integration of engine/propulsion system**
- **Fault finding and rectification**
- **Repair maintenance and**

documentation Practical flying with

instructor (01 Class) Day 04:

Practical flying with instructor/solo flying

(full day) Day 05:

Practical flying with instructor/solo flying (full day)

SAMPLE OF RPA LOG BOOK

RPA LOG BOOK

Name of the Owner/Operator:

Address of Owner/Operator:

SAMPLE CONTENTS OF RPALOG BOOK

1.	UIN	
2.	Category of RPA	
3.	Date of flight	
4.	Name of Remote Pilot	
5.	Place &time of commencement of operation	
6.	Place &time of termination of operation	
7.	Hours of flight (00:00 hrs)	
8.	Remote pilot observation (if any)	
9.	Record of maintenance as prescribed by manufacturer	
10.	Compliance record of other instructions issued by manufacturer	

Date: **(Signature of Remote Pilot)**

Annexure-XI

APPLICATION FOR GRANT OF PERMISSION FOR AERIAL PHOTOGRAPHY/ REMOTE SENSING SURVEY

(To be submitted in seven copies)

1. **Name and details of the company/agency seeking permission for aerial photography/Remote Sensing Survey with its registered office address.**

2 **Detail of person(s)/company intends to undertake photographs/aerial survey on behalf of agency at Para 1 above.**

- **a) Name (expanding Initials)**
- **b) Father's name**
- **c) Date and place of birth**
- **d) Present address**
- **e) Permanent address**
- **f) Nationality (if foreigners, information at Sl. No. (g) & (h) may also be provided)**
- **g) Passport No., date of issue & issuing authority**
- **h) Visa particulars including type, No., date, validity & issuing office**

3. **a) Purpose of aerial photography/aerial survey**
   - **b) Objects to be photographed with exact location i.e. latitude/ longitude**
   - **c) Scale of photography**
   - **d) Focal length of camera**
   - **e) Height of the flight**
   - **f) Format size**
   - **g) Type of camera/sensor being used**
   - **h) Type of data**

4. **Proposed date when aerial photography/aerial survey is to be undertaken**

5. **Description of RPA, along with the name and address of the owner and the remote pilot (if owner/pilots are foreigner, information in Sl. No. 2 (g) and (h) be also provided).**

6. **In case the task is to be carried out for State/ Central Government, copy of authority from the concerned Government be provided. Undertaking to comply with the following conditions and any other conditions as prescribed, if permission is granted:**

   - **a) Photography/ remote sensing survey will be confined to the exact area as applied and cleared by the Ministry of Defence.**
   - **b) No photography/ survey will be undertaken in the area so specified by the Ministry of Defence.**

c) The exact date and time of actual photography/ remote sensing survey will be intimated to Air Hqrs. (Directorate of Intelligence) at least two weeks in advance to enable them to detail a Security Officer.

d) The Security Officer of the Ministry of Defence will be positioned at the launching site of aerial photography, if considered necessary.

e) Air Hqrs. (Directorate of Intelligence) will be intimated on completion of photo/survey task and for detailing another Security Officer to check the cover plots/ photo products/digital data as required.

f) In cases where it is not considered necessary to depute security officer by the Ministry of Defence, the exposed film will be processed and plotted but not issued for use till security vetted by a representative of the Air Hqrs. (Directorate of Intelligence).

g) In case so specified by the Ministry of Defence in their clearance letter, the film/digital image after exposure will be processed in the presence of Air Force representative designated who will vet them from security angle before releasing them.

h) Government will not be liable for any loss or damages of films/digital data while in their custody.

i) Where exposed films/ digital data have to be conveyed outside India because facilities to develop/ process them do not exist in the country, Ministry of Defence will be informed of this fact at the initial stage of application.

Date:

(Signature of the applicant)
Name :
Designation :

Note: Strikeout whichever is not applicable

LIST OF IDENTIFIED AREA FOR TESTING/ DEMONSTRATION OF RPAS

State	Name of Place	Coordinates
	North	
Punjab	Phagwara	31° 17' 00" N 75° 48' 00" E
Uttarakhand	Sakkhanpur Farm	29° 18' 15" N 79° 03' 05" E
Uttar Pradesh	Lucknow, Shivgarh Resorts	26° 36' 27" N 81° 00' 42" E
Uttar Pradesh	Sultanpur	26° 14' 52" N 82° 02' 33" E
	South	
Karnataka	Chitradurga	14° 23' 17" N 76° 34' 19" E
Karnataka	Ganimangala Village	12° 13' 02" N 76° 37' 33" E
Kerala	Munnar,Devikulam	10° 03' 23" N 77° 07' 11" E
Kerala	Idukki	09° 55' 08" N 77° 06' 08" E
Tamil Nadu	Vellore	12° 54' 31" N 79° 04' 00" E
Tamil Nadu	Coorg, Choudigudi Estate	12° 07' 25" N 76° 03' 42" E
Tamil Nadu	Salem, Pullagoundanpatti	11° 28' 49" N 77° 43' 19" E
Tamil Nadu	Erode, Nambiyur	11° 21' 28" N 77° 19' 14" E
Tamil Nadu	Coimbatore, Chettipalayam	10° 54' 47" N 77° 02' 12" E
Telangana	Hyderabad, Mulugu Village	17° 43' 41" N 78° 42' 02" E
	East & NE	
Assam	Sonapur, Betkuchi	26° 08' 29" N 91° 57' 17" E
Assam	Sivasagar	26° 58' 57" N 94° 38' 32" E
Arunachal Pradesh	Daporijo Airfield	27° 59' 07"N 94° 13' 18" E
	West	
Gujarat	Surendranagar	22° 46' 26" N 71° 40' 02" E
Maharashtra	Shirpur Airport	21° 19' 43" N 74° 57' 40" N
Maharashtra	Amravati	20° 53' 48" N 77° 46' 30" E
Maharashtra	Aurangabad	19° 57' 00" N 75° 15' 00" E
Maharashtra	Ahmednagar	19° 05' 42" N 74° 44' 58" E
Maharashtra	Satara	17° 40' 49" N 74° 01' 05" E

Note:
The above list of Identified Area for Operation of RPAS excludes the restricted areas notified by various Government agencies.

ROLES & RESPONSIBILITIES OF GOVT. STAKEHOLDERS ON VARIOUS ASPECTS OF OPERATION OF CIVIL REMOTELY PILOTED AIRCRAFT SYSTEM

No.	Stakeholder	Responsibility
1.	Directorate General of Civil Aviation	Import clearance Issuance of UIN Issuance & renewal of UAOP Enforcement (Cancellation/Suspension of UIN/UAOP) in case of violations of regulation
2.	Directorate General of Foreign Trade	Import license
3.	Ministry of Home Affairs	Security clearance
4.	Ministry of Defence	Permission for aerial survey/imageries/ videography/ still photography over the restricted/prohibited areas on case-to-case basis
5.	Indian Air Force	Air Defence Clearance. Monitoring of RPA movements in the country. Monitoring RPA movements in the country
6.	Wireless Planning and Coordination Wing, DoT	Equipment Type Approval
7.	Bureau of Civil Aviation Security	Approval of Security Programme
8.	Airport Authority of India	Publication of guidelines for operation of RPAS in civil airspace in AIP. Approval of RPAS Flight Plan and issuance of ATC Clearance to RPAS, where applicable. Issue of Drone NOTAM when required. Segregation of RPAS operations from manned aircraft movements. Reporting of incidents / accidents involving known or controlled RPAS to DGCA.
9.	Local Police Office	Enforcement of violators as per applicable IPCs

MINIMUM STANDARDS FOR MANUFACTURING OF SMALL AND ABOVE CATEGORIES OF RPAS (BOTH INDIAN & FOREIGN)

Design/ Manufacturing Standards:

a. **All-up-weight**
b. **Wing span/rotor diameter (as applicable)**
c. **Stall speed**
d. **Cruise speed (minimum and maximum speeds at which the RPA remains stable and operational need to be established)**
e. **Range (maximum range travelled in still air, to be established)**
f. **Endurance**
g. **Operational altitude**
h. **Ceiling height**
i. **Propeller speed and pitch for safe operation**
j. **Powerplant - engine/battery operated (utility of source of supplying power to the RPA, and its adequacy to support the RPA during its entire operational phase, must be demonstrated).**
k. **Payload (strength requirements to be specified in term of limits loads i.e. maximum loads to be expected in operation. Simplified structural design criteria may be used for RPA. The structure must be able to support limit loads without detrimental, permanent deformation).**
l. **Shock absorbing mechanism of RPA need to be established to ensure that in the event of rough landing, structure is not damaged.**
m. **RPA must achieve sufficient energy and controllability at the end of the launch to ensure safe and controllable fly-away under any operating conditions.**
n. **Type of data-link used for communication (frequency band etc.).**
o. **Type of material for construction (to meet approved specifications for ensuring strength and other properties assumed in the design data).**
p. **Fabrication Method (methods of fabrication used for designing RPA must produce consistently sound structure).**
q. **Structure must be suitably protected against deterioration or loss of strength in operation due to any cause i.e. weathering, corrosion and abrasion.**
r. **Fire resistant identification plate on RPA for inscribing UIN.**
s. **Compliance to Digital Sky Platform Specifications for "No Permission – No Takeoff (NPNT)" for small and above RPA. (NPNT Specifications available in DGCA RPAS guidance manual).**
t. **Instruments/ Equipment and Qualification Testing**

i) **Instruments/ Equipment**

Global Navigation Satellite System (GNSS) receivers for horizontal and vertical position fixing.
Geo-fencing capability.
Autonomous Flight Termination System or Return Home (RH) option. Flashing anti-collision strobe lights.
RFID and GSM SIM Card.
Flight controller with flight data logging capability.
SSR transponder (Mode 'C' or 'S') or ADS-B OUT equipment.
Barometric equipment with capability for remote sub-scale setting. Detect and Avoid capability.

ii) **Qualification testing Environmental tests**

EMI/ EMC test.
Any other tests carried out by the OEM.

45.BASICS OF DRONE TECHNOLOGY

45.1. Unmanned Aircraft Systems

45.1.1. Definition

An unmanned aerial vehicle is an aircraft without a human pilot on board and are more commonly called as “Drones”. These are operated with various degree of autonomy, i.e., either under remote control by a human operator or autonomously by onboard computers UAVs typically divided in to five functional categories:

- **Target and decoy** – Providing ground and aerial gunnery a target that simulates an enemy aircraft or missile Reconnaissance – providing battlefield intelligence
- **Combat** – Providing attack capability for high-risk missions also called as UCAV (Unmanned combat aerial vehicle)
- **Logistics** – Delivering cargo - Amazon
- **Research and development** – Improve UAV technologies
- **Civil and commercial UAVs** – Agriculture, aerial photography, data collection, mapping

There are Four main types of Drones

(i) Multirotor

(ii) Fixed wing

(iii) Helicopters

(iv) VTOL fixed wings / Hybrid fixed wings

The sub classification of Multirotors

- Bi Copter
- Tri copter
- Quad copter
  - Quad H
  - Quad X
  - Quad +
- Hexa copter
  - Hexa X
  - Hexa +
- Octa copter
  - Octa X

The Sub Classification of Fixed wing Drones

- Electric based
- Engine Based
- Hybrid Fixed wing
- LALE fixed wing
- HALE fixed wing
- MALE fixed wing

45.1.2. Multirotors

It is a rotorcraft with more than two rotors. An advantage of multirotor aircraft is the simpler rotor mechanics required for flight control.

45.1.3. Rotor

The rotor is a moving component of an electromagnetic system in the electric motor, electric generator, or alternator. Its rotation is due to the interaction between the windings and magnetic fields which produces a torque around the rotor's axis

45.2. Types of drones:

45.2.1. Bi copter

A Bicopter is the cheapest to build, but it is highly unstable. With two servos and two motors, achieving stable flight can be a challenge. But later more stable designs have been introduced.

Figure: Bi-copter

45.2.2. Tri copter

A tri-copter has three vertical rotors. The functions are simple, A tricopter is primarily used by hobby and winger. This is also easy to build and repair themselves even make it cheaper. But the model is unstable cannot use for longer range and better flying.

Figure: Tri-copter

45.2.3. Quadcopter

45.2.3.1. Definition

A quadcopter, or Multirotor, drone, or quad rotor, is a simple flying mechanical vehicle that has four arms, and in each arm there is a motor attached to a propeller. Multicopters with three, six or eight arms are also possible, but work on the same principal as a quadcopter. Two of the rotors turn clockwise, while the other two turn counter clockwise. Quadcopters are aerodynamically unstable, and require a flight computer to convert our input commands to change the RPMs of the motors.

45.2.3.2. Quadcopter Dynamics

There are four main forces that act on a quadcopter

(i) **Gravity** – This is the force that pulls the quadcopter down due to its mass.
(ii) **Lift** – This is the upward reaction force on the quadcopter due to the propellers.
(iii) **Thrust** – This is the horizontal reaction force on the quadcopter due to the
(iv) **Drag** – This is the backward force on the quadcopter due to air. For e.g., Imagine being in a **car**, and putting our hand outside the window. The air hitting our hand is trying to push back.

Figure: Quad copter

45.2.4. Hexacopter

Hexacopter is having six propellers. They are arranged in a circular shape above the main body of the hexacopter. This body often carries a camera and features two legs shaped like skis. These skis allow the device to be stable when it lands.

Pros

The six propellers give this craft more maneuverability and flying power than a quadcopter. The craft can fly very steadily and reach higher altitudes than a quadcopter too. This is because it has more lifting power. If we are using an expensive camera to capture footage with this craft, we can be sure that it is can fly the camera without any stability problems. Due to the 6 propellers, a hexacopter can achieve altitudes that are way higher than quadcopter can achieve. This is because the propellers give it more uplift power than that of a quadcopter. This drone can fly faster than a quadcopter. Again, this is as a result of more propellers. A hexacopter has more load carrying capacity than a quadcopter. Thus, we can attach more payload to it than a quadcopter. As such, we can carry a high performance camera with a hexacopter.

Cons

Hexacopters are more expensive to build than quadcopters. The extra rotors cost more. In addition, that, they are larger than quadcopters. As such, they are not as compact. If they get damaged, rotors of a hexacopter are more expensive to repair or replace.

Figure: Hexa-copter

45.2.5. Octocopter

Octocopters can carry heavy payloads but with low range compare to the quadcopters.

Pros (Octocopter compared to quadcopters and hexacopters:

- Incredibly fast and agile
- Reach higher altitudes
- More powerful and reliable
- Capable of lifting heavier camera equipment
- Extra safety features
- Very stable flyers, handle better in adverse weather conditions

Cons

Each model gets bigger, heavier, and less luggable. The price tag goes up and the battery life (flight times) can go down because of the extra weight and increased power. These are the main differences between quadcopters, hexacopters, and octocopters.

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Figure: Octo-copter

45.3. Drone Orientation

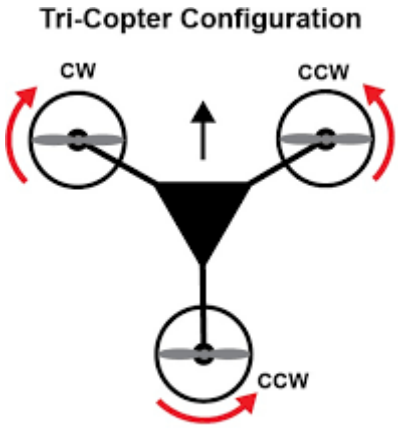


Figure: Tri-copter Orientation

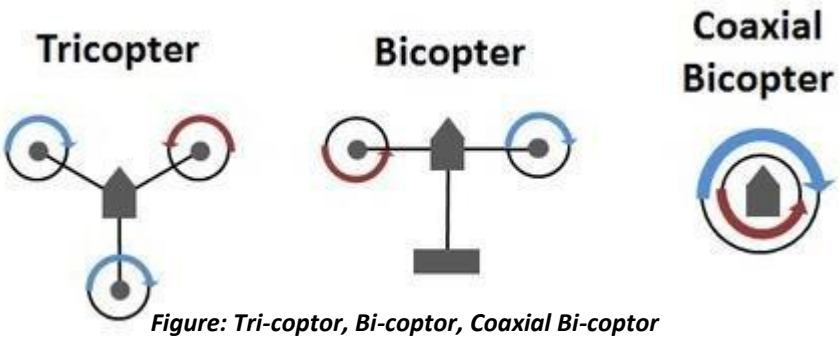


Figure: Tri-coptor, Bi-coptor, Coaxial Bi-coptor

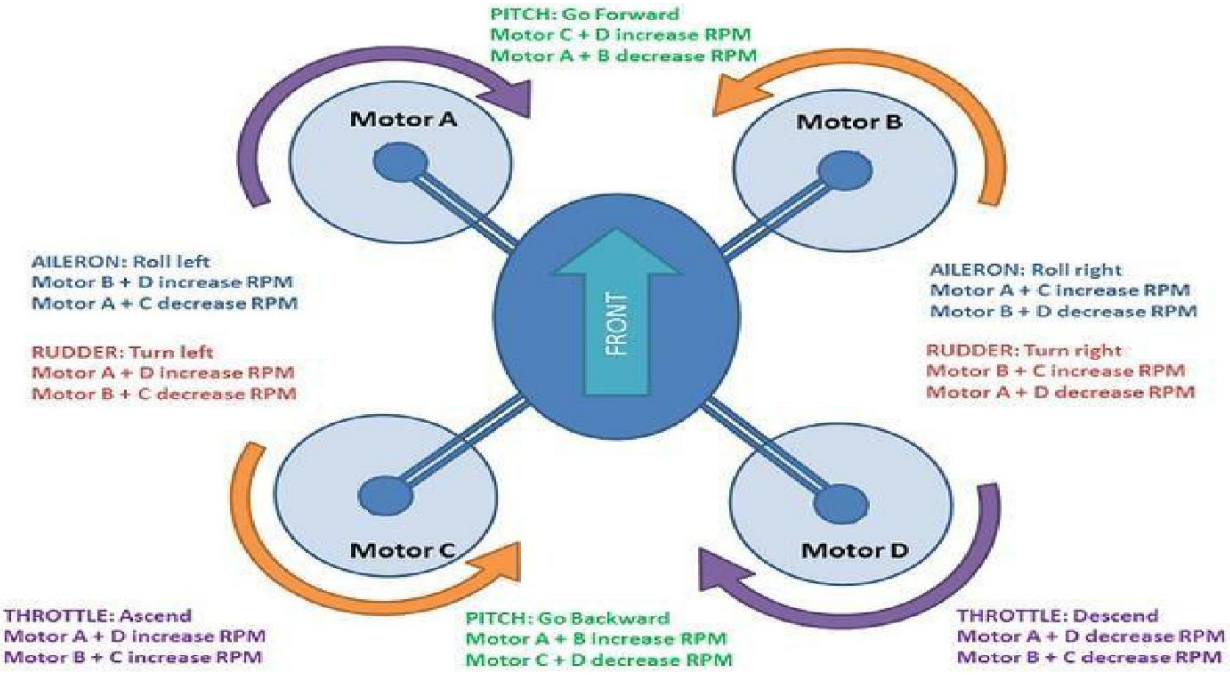


Figure: Orientation of Quadcopter

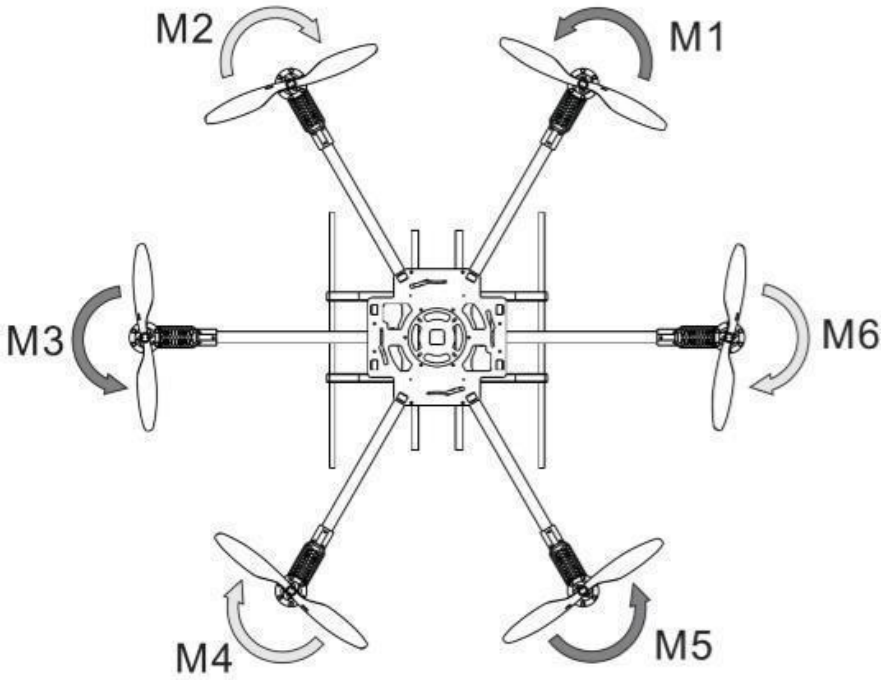


Figure: Orientation of Hexa copter

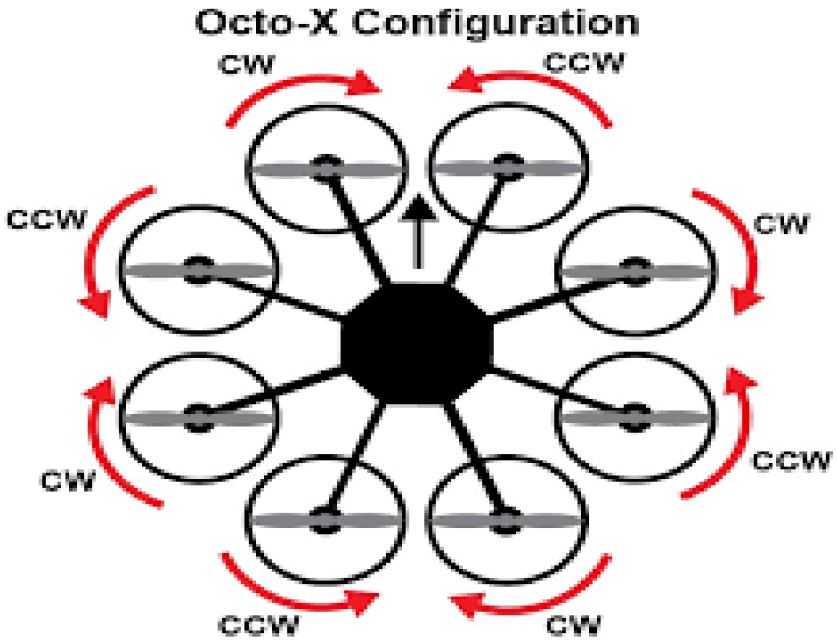


Figure: Octocopter Orientation

45.4. Bernoulli's Principle

To understand how lift is produced, we must examine a phenomenon discovered many years ago by the scientist Bernoulli and later called Bernoulli's Principle.

45.4.1. Definition

The pressure of a fluid (liquid or gas) decreases at points where the speed of the fluid increases. In other words, Bernoulli found that within the same fluid, in this case air, high speed flow is associated with low pressure, and low speed flow with high pressure. This principle was first used to explain changes in the pressure of fluid flowing within a pipe whose cross-sectional area varied. In the wide section of the gradually narrowing pipe, the fluid moves at low speed, producing high pressure. As the pipe narrows it must contain the same amount of fluid. In this narrow section, the fluid moves at high speed, producing low pressure.

An important application of this phenomenon is made in giving lift to the wing of an airplane, an airfoil. The airfoil is designed to increase the velocity of the airflow above its surface, thereby decreasing pressure above the airfoil. Simultaneously, the impact of the air on the lower surface of the airfoil increases the pressure below. This combination of pressure decrease above and increase below produces lift.

Probably we have held our flattened hand out of the window of a moving automobile. As we inclined our hand to the wind, the force of air pushed against it forcing our hand to rise. The airfoil (in this case, our hand) was deflecting the wind which, in turn, created an equal and opposite dynamic pressure on the lower surface of the airfoil, forcing it up and back. The upward component of this force is lift; the backward component is drag.

45.4.2. Multirotors works under the Principle of Bernoulli's

An airfoil is a device which gets a useful reaction from air moving over its surface. When an airfoil is moved through the air, it is capable of producing lift. Airfoil examples are wings, horizontal tail surfaces, vertical tails surfaces, and propellers are all examples of airfoils.

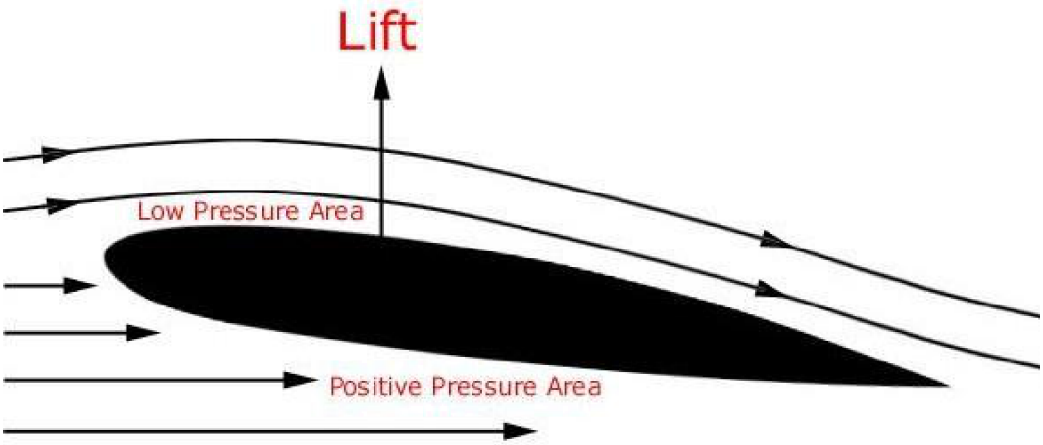


Figure: Air flow direction over airfoil

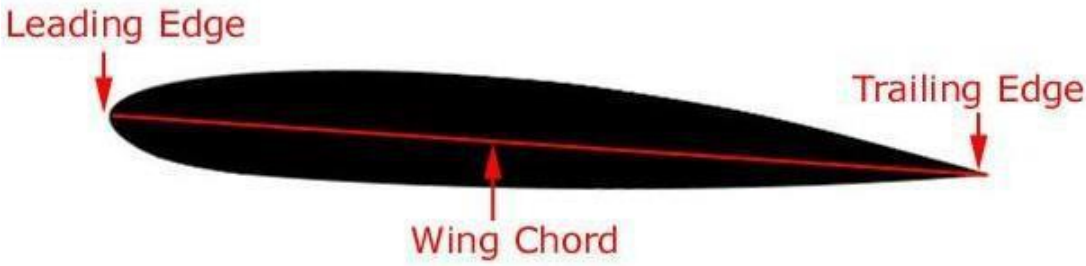


Figure: Airfoil design

Generally the wing of small aircraft will look like the cross-section of the figure above. The forward part of an airfoil is rounded and is called the leading edge.

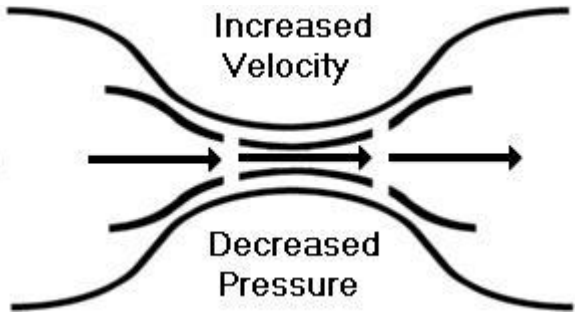


Figure: Difference in Pressure & Velocity

The aft part is narrow and tapered is called the trailing edge. A reference line often used in discussing airfoils is the chord, an imaginary straight line joining the extremities of the leading and trailing edges.

46.LIST OF COMPONENTS REQUIRED TO MAKE A DRONE (QUAD COPTER)

Components Required

- Transmitter and receiver
- Frame
- Flight controller
- Power distribution board
- 4 ESCs
- 4 motors
- 4 prop adapters
- LiPo - battery
- Charger / Voltage checker
- adapter for any battery
- Power supply
- Propellers (2 clock wise and 2 anti-clockwise)
- Tall nylon spacers
- Short nylon spacers
- 3.5mm bullet connectors
- Velcro (to tighten the battery)

Tool Kit Required

- Soldering gun
- Screw driver kit
- Allen key
- Tester
- Multimeter
- Double sided tape
- cello tape

Note: Do not power up until we do the connectivity check for the power distribution board using multimeter.

46.1. Transmitter Box

A radio control system is made up of two elements, the transmitter we hold in our hands and the receiver we put inside our drone. Dramatically simplifying things here, our drone transmitter will read our stick inputs and send them through the air to our receiver in real time. Once the receiver has this information it passes it on to our drones flight controller which makes the drone move accordingly. A radio will have four separate channels for each direction on the sticks along with some extra ones for any auxiliary switches it may have.

46.1.1. Frequency and channels

Frequency and channel wise radio controls are lot smarter than FPV counter parts and are much easier to manage. Video transmitters and receivers for example both require setting to the correct channel along with diligent channel management every time we fly. A Radio Controller however simply needs to bind or pair with a receiver at the first time Always link and hop over various frequencies in the 2.4Ghz band to ensure a solid link, theoretically hundreds of pilots operating at the same time.

46.1.2. Range technology

The limit of range is normally where the receiver can no longer clearly hear what the transmitter sends and typically falls in the 1km range in normal conditions. Imagine trying to talk to someone across a field, The range of our radio link will be dependent on a few factors:

- **The output power of our transmitter** - Many run just below the legal maximum to be compliant with international standards.
- **The sensitivity of the Receiver** - A more sensitive receiver is like having better hearing, the signal will travel further however it may pick up more noise in certain conditions
- **The quality of our antennas at both ends** - Antenna will send and receive a better signal. Often optimizing our antenna placement will make a huge difference to the system performance. Although typical radio systems use the 2.4Ghz band, specialist long range systems such as the TBS Crossfire can run on much lower frequencies which can travel much further with the same power.

46.1.3. Comparability and Communication Protocols

Different radios and receivers communicate with their own language. In order to be faster and more reliable we must use a receiver that is compatible with the transmitter that is more likely of the same company.

Once the receiver has the signal it needs to communicate it to the flight controller. Different radios have different protocols for this and it is important to make sure that our flight controller and software supports it. The communication speed is important, otherwise it could introduce a delay in our system.

Some standard protocols include

10. **PWM** - This is our classic analogue signal with one separate wire for each channel. This is now slow and outraged and should be avoided if possible
11. **PPM** - This is a slightly improved version of **PWM** where all the channels are sent over one wire as a series of timed pulses. This is quicker than **PWM**. However, it is still not the best option.

46.1.4. Choosing a Radio

When choosing a radio and receiver combo whilst comparing some of the options out there.

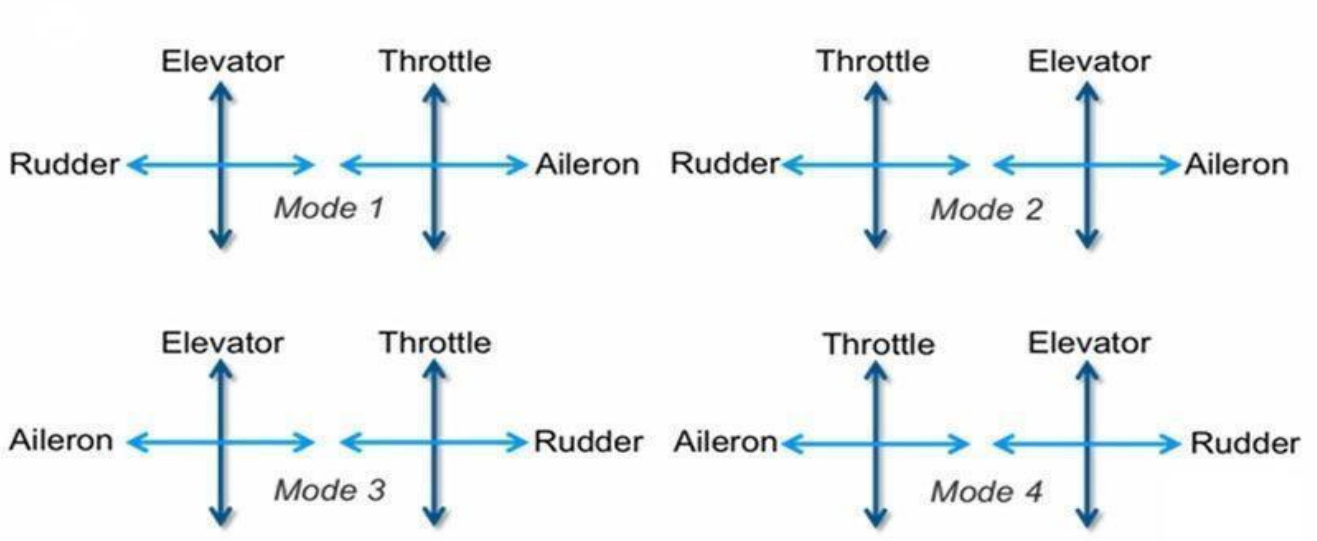


Figure: Comparing different Radio and Receiver Modes

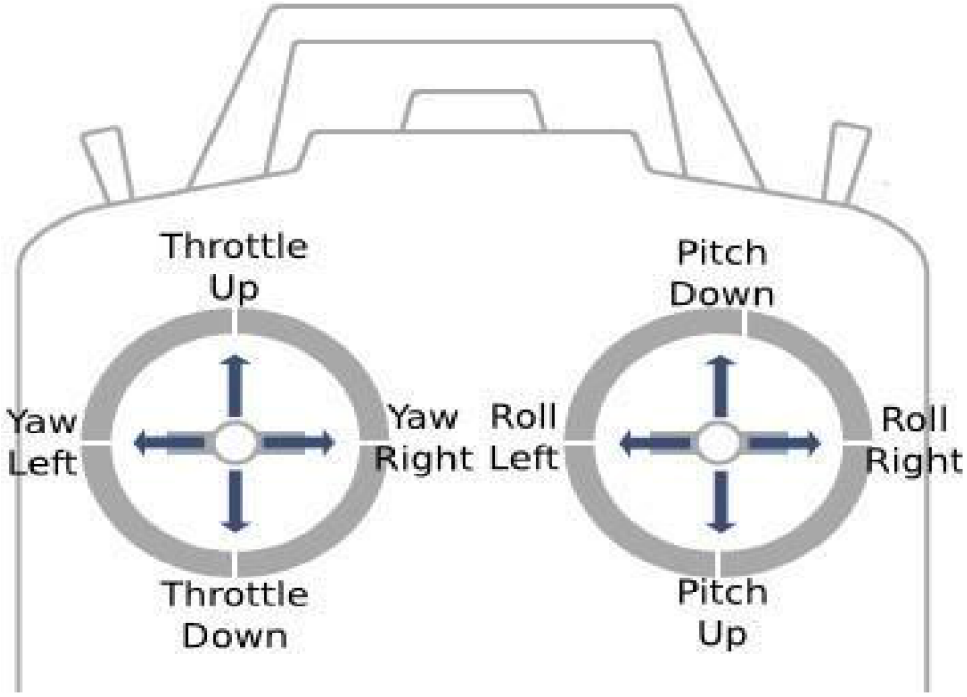


Figure: Transmitter Box: Mode

We have looked at some radios online and may noticed that many give us an option to choose a different mode (eg Mode 1,2,3 or 4). These modes represent which stick does what for example which stick is the throttle.

The most common mode for mini quad pilots is **Mode 2** with the throttle on the left. We would suggest to stick with mode 2, unless we have prior experience with other modes.

Once we adapt to a particular mode it will be challenging for our muscles and brain to switch! If we do go for a more exotic mode, it's a choice for us and won't affect anything else. Many radios allow us to open up the gimbals and switch modes.

46.1.5. Gimbal

46.1.5.1. Definition

The gimbals are the sticks that we use to control our mini quad. For mode two pilots we will have one on the left controlling throttle and yaw leaving pitch and roll to the right hand gimbals. Good gimbals can be adjusted for size, tension and can have customizable stick ends. Some gimbals have better quality sensors such as hall sensors.

These rely on magnets instead of a brushed joint which give a much smoother feel and more precise flight experience.

46.1.6. Pinch or Thumbs?

Figure: Transmitter Box

The gimbals on a transmitter are much longer than an Xbox or Play station controller and there is no right or wrong way to hold them.

Typical options include pinching the sticks between our index finger or thumb or by just using our thumb on it's own. In general, whatever radio we choose, we should read some reviews to check if they are pinch or thumb friendly.

Thumbers typically want shorter sticks and a narrower radio so that they can grip the back. As a pincher we want longer travel but we have to be aware of any potential switches that could knock by accident. They may also require a neck strap.

46.1.7. Switches

Figure: Switches in Transmitter Box

Transmitters along with gimbals, they also have an array of switches that can be used for arming and changing flight modes etc.

Switches come in two or three position forms as well as sliders, however as mini quad pilots we don't really need to compare with aircraft flyers or any other professional fliers. We would suggest having a radio with four configurable switches will cover everything that could ever need.

46.1.8. Transmitter Channels

Each transmitter switches will require its own channel and the gimbals require two (each one for each direction). That means a six channel radio will only let use the gimbals and two switches even if it has more. Higher end radios will give us up to 16 channels which is more than we can ever need. If we are planning anything special make sure we have enough channels free to make it all possible. High end radios will have built in Li-ion batteries with a built in charging circuit allowing us to charge us radio with a simple DC jack. These typically will last for days before they need charging and is most peoples preferred option.

The cheaper radios on the other hand may not come with batteries and run on AA batteries. This is something worth considering when buying a budget radio transmitter with more than we would expect in the long run.

The only advantage to this type of battery is that they are readily available and can be swapped with little down time. In the middle category of radios that can run off lipo batteries but they will require us to charge them separately.

On the plus side we get the long battery life at a low cost however we also have to source, charge and manage a LiPo by ourselves. Some radios may also come with NiMH batteries which will not last as long.

46.2. FRAME

Having the best multirotor frame is of paramount importance to ensure that we are building our beloved multicopter on a quality frame that is compatible with all the electronic components needed.

In fact, it is equally important and relative to choosing the best electronic components such as the Electronic Speed Controls (ESCs), propellers, arms, and motors. A wrong choice of any of these may spell a disaster. As experts in drones, we have chosen to help we get familiar with how to pick the best multirotor frame.

But first, we do not intend to give we the best model because, in a true sense, there is no a generic frame considered to be the best among all the frames. We are, however, well- equipped with guidelines on how to find the best one to meet our quest of building our own drone.

Figure: Qaud-coptor Frame

We probably know that there are different types and configurations of multicopter frames. As such, we will expand on such classifications of frames as we endeavor to refine our search. We can also work on some frames that could be the best choices for specific frame configurations.

46.2.1. What To Look For When Buying The Best Frame?

Firstly, we need to determine our purpose. For instance, have we decided that what are we going to use our drone for? For fun? Racing? Aerial cinematography? For sport? And, how many motors do I need? In reality, there could be a plenty of purposes that we want to use the copter for. we will be lucky to find out that our copter frame is versatile.

Figure: Motors in Quad-coptor

For instance, some can be used for professional aerial cinematography and simultaneously for recreation purposes. The bottom line is that, various Multirotor frames have varying purposes of use, and can do well in the predetermined purposes than others. Let's explore these purposes below.

46.2.2. Purpose Of Buying The Multirotor Frame

46.2.2(i) Aerial Cinematography

If we plan to indulge in aerial cinematography, where an excellent high definition camera like the expensive GoPro HERO models is needed to take quality aerial images, we will have to buy stiff but less brittle frames to provide a smooth and stable flight. Such frames should be huge enough and solid, so that they can easily hold the big models of cameras needed for this professional aerial activity.

Figure: Flying Inspire

Furthermore, the frames should be supportive of tall landing gear needed to secure the camera when the multicopter lands, or during the inevitable crash or emergency landing occur. However, the frame to be stiff, it should be light in weight. We can imagine the added weight of the camera when mounted that what will be the overall weight. That could be inconveniently too much.

46.2.2(ii) Mini Multicopter

The other purpose could be flying the multicopters indoors or outdoors, and we need to get mini multirotor frames. These frames are remarkably the lightest in weight. Quite often, the mini drones do not require much of efforts or many components to get them going. We do not have to mount larger cameras. So, in a nutshell, we need light frames for indoor flying and most of these are quadcopter frames.

Figure: Mini drone with Camera

Moreover, on the mini frames for drones, We can find the frames dedicated for mini FPV drones. These ones can be small too, but, one of the challenging to build. Take into account the mounting of FPV-designated electronics and the FPV camera. That being noted, these

FPV mini frames should be spacious enough to accommodate additional components than the regular mini drones.

46.2.2(iii) Sports Drone

For sport-dedicated drones, We need light frames for high speed. We may choose not to mount the camera on such drones because it might compromise their speed capabilities due to added pounds. But, the drones should be stable enough and responsive to a plethora of acrobatics – thus not to be jeopardized by unstable light frames.

The material of the frame is the determining factor with regard to the stability. As an example, carbon fiber frames have been used frequently for these types of frames.

Figure: Sports Drone

But then, as in the option of FPV in mini drones, some sport drones may be compatible with FPV. With this range of FPV copters potential frame is mounted to carry FPV cameras. As a result of this, these frames should be firm enough to hold an additional weight of the camera and other electronic devices. Any frame with a light weight not capable of holding cameras. It may struggle during takeoff.

Now that we know about what kinds of drones needed for various purposes, let's get into some properties needed such as the stiffness, materials and the arms. Drone frames are predominantly categorized based on materials used in their design, in addition to the shape and the dimensions.

46.2.2(iv) Important properties to look for

- **Materials**

The first thing in our mind should be the materials when picking the best frame. The materials play a significant role in determining the drone's stability and efficient performance. Note that vibration is increasingly a nuisance in many drones, and it could lead to poor quality aerial images and possible damage to the electronic components.

Figure: Carbon Fibre Frame

Most frames are designed with carbon fibers because of its light weight properties. However, the downside of carbon fibers is radio signal interference. It is nonetheless a good material for our frame. To solve this, we must make sure that the radio and the antenna are connected effectively.

The other commonly used materials include the aluminum and fiberglass. Aluminum, on the other hand, it's a heavier metal to use on the frames, but it needs powerful motors. Although aluminum is more powerful and strong, it has a problem of an inevitable vibration.

Figure: Aluminum Frame

That's why it is not commonly used. Meanwhile the fiber glass provides a great deal of not interfering the radio signals. However, it comes second to carbon fiber in terms of stiffness and rigidity, because it can bend to affect the stability of our drone. It appears that every material has its downsides.

- **Stiffness of the frame**

The frame needs to be stiff. The stiffness enables the frame to be stable and smooth enough without any detrimental bends in the sky. A smooth flight will yield smooth and stable videos and photographs. Moreover, the frame should be brittle, but not too brittle. In fact, too much of something is bad news. For example, the drone is too brittle, it might be susceptible to the damage in crashes.

- **Arms**

We need to pay more attention on the arms as well. The material used in the arms should be effective in minimizing vibrations. But, in most cases, we may find the frames that come with the pre-built arms, thus negating the need to match the configurations with the frames when building our drone.

Figure: Arms in the Frame

To safeguard our frame from crashes, the arms should be strong enough because when the drone falls, they are the first to get damaged. They will be saving the drone's essential electronic components and the frame. A hard plastic or aluminium is often used.

- **Integration of devices**

When making a purchase, just make sure that it is accommodative of essential electronic components to be mounted. For instance, we need to fit the flight controller, motors, ESCs, etc. We might find some frames having holes with guidelines that where to fit certain devices.

Figure: Electronic Integration

In fact, assembling a drone from the frame is one of the challenging tasks that an amateur hobbyist will find exhausting. There could be some electronic boards that need to be drilled to fit in screws and wires. It all depends on the frame we bought. So, if we are not well- versed in such mechanism of assembling, rather opt for the easiest frame that is half-done.

- **Multirotor frame designs**

If we are an experienced UAV pilot, we might probably know the possible configurations. Anyway, it is still worth it to read through to understand further. It is also important to know these configurations when purchasing the frames. It all depends on our preference that how many motors do we intend to use in a frame.

46.3. Flight Controller

Now that we have chosen or designed a UAV frame, chosen the appropriate motors, propellers, ESCs and battery, we can start looking into choosing a flight controller. A flight controller for a multi-rotor UAV is an integrated circuit normally made up of a microprocessor, sensors and input / output pins. Out of the box, a flight controller does not magically know our specific UAV type or configuration, so we need to set certain parameters in a software program, and once complete, that configuration is uploaded to board. Rather than simply comparing flight controllers which are currently available, the approach we have taken here lists which feature serve which functions to use, as well as other aspects to look for.

46.3.1. Main Processor

46.3.1.1. Definition

(i) 8051 vs AVR vs PIC vs ARM: These microcontroller families form the basis of most current flight controllers. Arduino is AVR based (ATmel) and the community seems to focus on MultiWii as being the preferred code. Microchip is the primary manufacturer of PIC chips. It is difficult to argue that one is better than the other, and it really comes down to what the software can do. ARM (STM32 for example) uses 16/32-bit architecture, whereas AVR and PIC tens to use 8 / 16-bit. As single board computers become less expensive and expect to see a new generation of flight controllers which can run full operating systems such as Linux or Android.

(ii) CPU: Normally these are in multiples of 8 (8-bit, 16-bit, 32-bit, 64-bit) and is a reference to the size of the primary registers in a CPU. Microprocessors can only process a set (maximum) number of bits in memory at a time. More bits a microcontroller is, the more accurate (and faster) the processing will be. For example processing a 16-bit variable on an 8-bit processor is a bit of a chose, whereas on a 32-bit processor, it is very fast. Note that the code also needs to work with the right number of bits, very few programs use code optimized for 32 bits.

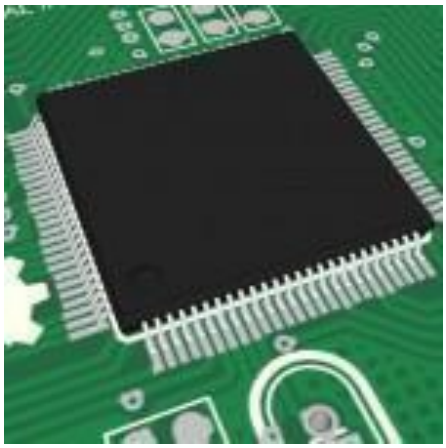


Figure: Microcontroller

(iv) Operating frequency: The frequency at which the main processor operates. Frequency is measured in "Hertz" (cycles per second). This is also commonly referred to as the "clock rate".

The higher the operating frequency, the faster it can process the data.

(v) Program Memory / Flash: The flash memory is essentially where the main code is stored. If the program is complex it may take up quite a bit of space. Obviously the greater the memory, the more information it can store. Memory is also useful when storing in-flight data such as GPS coordinates, flight plans, automated camera movement etc. The code loaded to the flash memory remains on the chip even if the power is cut.

(vi) SRAM: SRAM stands for "Static Random-Access Memory", and is the space on the chip which is used when making calculations. The data stored in RAM is lost when power is cut.
The higher the RAM, the more information will be "readily available" for calculations at any given time.

(vii) EEPROM: Electrically Erasable Programmable Read-Only Memory (EEPROM) is normally used to store information which does not change in flight, such as settings, unlike data stored in SRAM which can relate to sensor data etc.

(vii) Additional I/O Pins: Most microcontrollers have a lot of digital and analog input and output pins, and on a flight controller, some are used by the sensors, others for communication and some may remain for general input and output. These additional pins can be connected to RC servos, gimbal systems, buzzers and more.

(viii) A/D converter: The sensors used onboard output analog voltage (normally 0-3.3V or 0-5V), the analog to digital converter needs to translate these readings into digital data. Just like the CPU, the number of bits which can be processed by the A/D determines the maximum accuracy. The frequency at which the microprocessor can read the data (number of times per second) to ensure no information is lost. It is nevertheless hard not to lose some data during this conversion, so the higher the A/D conversion, the more accurate the readings will be, but it is important that the processor can handle the rate at which the information is being sent.

46.3.2. Power

46.3.2(i) Sensors

In terms of hardware, a flight controller is essentially a normal programmable microcontroller, but has specific sensors onboard. At a bare minimum, a flight controller will include a three axis gyroscope, but as such will not be able to auto-level. Not all flight controllers will include all of the sensors below and may include a combination thereof.

46.3.2(ii) Accelerometer

As the name implies, accelerometers measure linear acceleration in up to three axes (let's call them X, Y and Z). The units are normally in "gravity" (g) which is 9.81 meters per second, or 32 feet per second. The output of an accelerometer can be integrated twice to give a position, because of loss in the output, it is subject to "drift". A very important characteristic of three axis accelerometers is that they detect gravity, and as such, can know which direction is "down". This plays a major role in allowing multirotor aircraft to stay stable. The accelerometer should be mounted to the flight controller so that the linear axes line up with the main axes of the UAV.

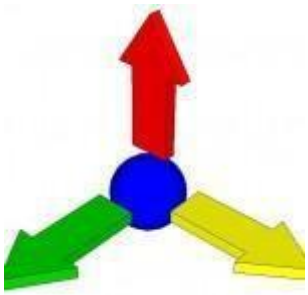


Figure: Accelerometer Axes

46.3.2(iii) Gyroscope

A gyroscope measures the rate of angular change in up to three angular axes (let's call them alpha, beta and gamma). The units are often degrees per second. Note that a gyroscope does not measure absolute angles directly, but we can iterate to get the angle just like an accelerometer, is subject to drift. The output of the actual gyroscope tends to be analog or I2C, but in most cases we do not need to worry about it since this is handled by the flight controller's code. The gyroscope should be mounted so that its rotational axes line up with the axes of the UAV.

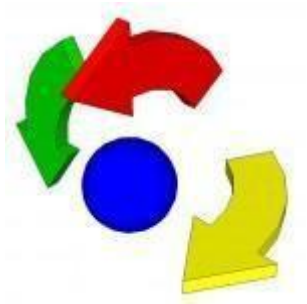


Figure: Gyroscope Axes

46.3.2(iv) Inertia Measurement Unit (IMU)

An IMU is essentially a small board which contains both an accelerometer and gyroscope (normally these are multi-axis). Most contain a three axis accelerometer and a three-axis gyroscope, and others may contain additional sensors such as a three axis magnetometer, providing a total of 9 axes of measurement.

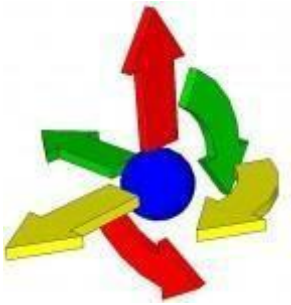


Figure: IMU 6 Axes

46.3.2(v) Compass / Magnetometer

An electronic magnetic compass is able to measure the earth's magnetic field and used it to determine the drone's compass direction (with respect to magnetic north). This sensor is almost present if the system has GPS input and is available in one to three axes.

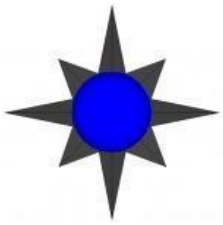


Figure: Compas

46.3.2(vi) Pressure / Barometer

Since atmospheric pressure changes from sea level, a pressure sensor can be used to give us an accurate reading for the UAV's height. Most flight controllers take input from both the pressure sensor and GPS altitude to calculate a more accurate height above sea level. Note that it is preferable to have the barometer covered with a piece of foam to diminish the effects of wind over the chip.

Figure: Atmospheric Pressure

46.3.2(vii) GPS

Global Positioning Systems (GPS) use the signals sent by a number of satellites in orbit around the earth in order to determine their specific geographic location. A flight controller can either have onboard GPS or one which is connected to it via a cable. The GPS antenna should not be confused with the GPS chip itself, and can look like a small black box or a normal "duck" antenna. In order to get an accurate GPS lock, the GPS chip should receive data from multiple satellites, and the more the better.

Figure: GPS Satellites

46.3.2(viii) Distance

Distance sensors are being used more and more on drones since GPS coordinates and pressure sensors alone cannot tell us how far away from the ground we are (think hill, mountain or building) or if we will hit an object. A downward-facing distance sensor might be based on ultrasonic, laser or Lidar technology (infrared has issues in sunlight). Very few flight controllers include distance sensors as part of the standard package.

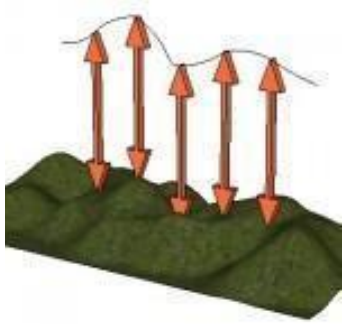


Figure: Distance

46.3.2(ix) Flight Modes

A “flight mode” is the way, the flight controller uses sensors and RC input in order to fly and stabilize the aircraft. If we have a transmitter with five or more channels, we may configure the software to allow us to change the flight mode via 5th channel (aux switch) while in flight.

46.3.3. Software

46.3.3(i) PID Control Loop & Tuning

Proportional Integral Derivate (PID) control allows us to change the drone‘s flight characteristics, including how it reacts to user input and quickly it stabilizes and more. The PID settings and the software uses the various sensor inputs are important, but without seeing and understanding the code which dictates this is not too useful when comparing flight controllers. Manufacturer which produce “ready to fly” kits are able to fine tune the PID settings and equations for their specific platform, that's why most RTF muti-rotors fly quite well out of the box. Builders of custom drones however need to use flight controllers which are designed to be suitable for almost any type of multi-rotor aircraft, and as such it is up to the end-user to adjust the values until they are satisfied with the flight characteristics.

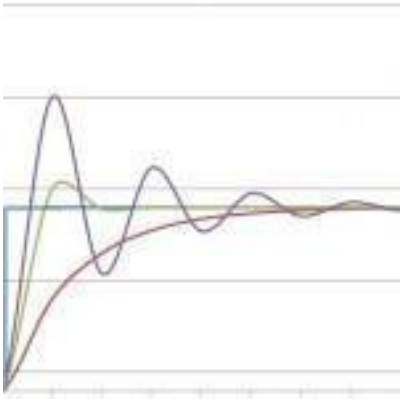


Figure: PID Graph

46.3.3(ii) GUI

A GUI (Graphical User Interface) is what is used to visually edit the code (via a computer) which will be uploaded to the flight controller. The software provided with flight controllers continues to get better and better; the first flight controllers on the market used largely text-based interfaces which required that we understand almost all of the code and change specific sections to suit our project. More recently flight controller GUIs use interactive graphical interfaces to help we configure the necessary parameters.

Figure: Quadrino GUI

46.3.3(iii) Additional Features

The software used on certain flight controllers may have additional features which are not available on others. Our selection of a specific flight controller may ultimately depend on which additional features / functionality are offered. These features can include:

- Autonomous waypoint navigation, which allows us to set GPS waypoints in which the drone will follow autonomously.
- "Oribiting" i.e. moving around a fixed GPS coordinate with the front of the drone always pointed towards the coordinate (useful for filming).
- "Certain drones have a "follow me" feature which can be GPS based (for example tracking the GPS coordinates of a smart phone).
- 3D imaging: Most 3D imaging is done after a flight using images captured during the flight and GPS data.

46.3.4. Different types of Communications

46.3.4.1. Open Source

The software associated with certain flight controllers cannot be modified / customized. Open-source products generally allow advanced users to modify the code to suit their specific needs.

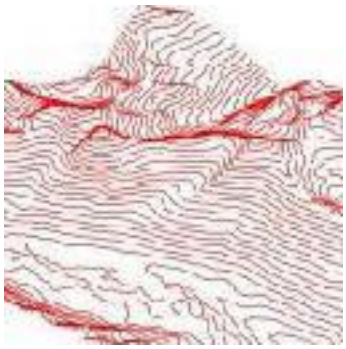


Figure: Communication

46.3.4.2. Bluetooth

Bluetooth, and more recent BLE (Bluetooth Low Energy) products were originally intended to be used to transfer data between devices without the complexity of pairing or matching frequencies.

Certain flight controllers on the market can send and receive data wirelessly via Bluetooth connection, making it easier to troubleshoot issues in the field.

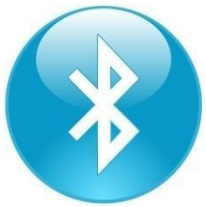


Figure: Bluetooth

46.3.4.3. WIFI

WIFI control is normally achieved using a Wi-Fi router, computer (including laptop, desktop, tablet) or smart phone. Wi-Fi is able to handle both data transmission as well as image transmission, but is much more difficult to set up / implement. As with all Wi-Fi devices, the range is limited by that of the Wi-Fi transmitter.

Figure: WIFI

46.3.4.4. Radio Frequency (RF)

Radio Frequency (RF) control in this context refers to sending data from a computer or microcontroller wirelessly to the aircraft using an RF transmitter / receiver (two-way transceiver). Using a normal RF unit connected to a computer allows for long range two-way communication with a high “density” of data (normally in serial format).

Figure: Radio Frequency (RF)

46.3.4.5. Smart Phone

Although this is not a type of communication, the question is how to control a drone using a smart phone?. Modern smart phones are essentially powerful computers which coincidentally can also make phone calls. Almost all smart phones include integrated Bluetooth as well as WiFi either of which are used to control the drone and/or receive data and/or video.

Figure: Smart Phone

46.3.4.6. Infrared (IR)

Infrared communication (like what we find in a television remote control) is rarely used to control drones as there is so much IR interference present even in normal rooms (let alone outdoors) that it is not very reliable. Although it can be done, it is not suggested as a primary option.

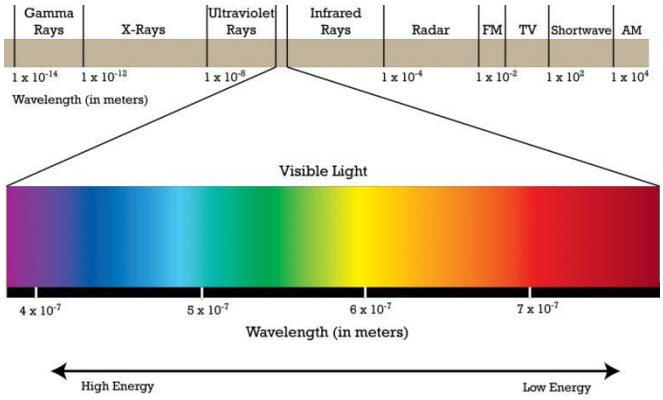


Figure: Infrared (IR)

46.4. POWER DISTRIBUTION BOARD (PDB)

46.4.1. Definition

PDB's are often an overlooked area of multirotor drone building, mainly because they are fairly simple but despite, they are a crucial part of our drone and if we don't choose the right one we could end up losing our drone.

As the name suggests, a PDB distribute the power on our drone, and provides a neat and tidy way of connecting our battery to all of our ESC's on our aircraft. A PDB has positive pads/terminals which are all connected and negative terminals/pads which are all connected. We solder all of the red wires from our ESC's and battery to the positive pads on the PDB, and the black wires to all the negative pads, they all will get connected so our battery can provide power to all of our ESC's as shown in the image below.

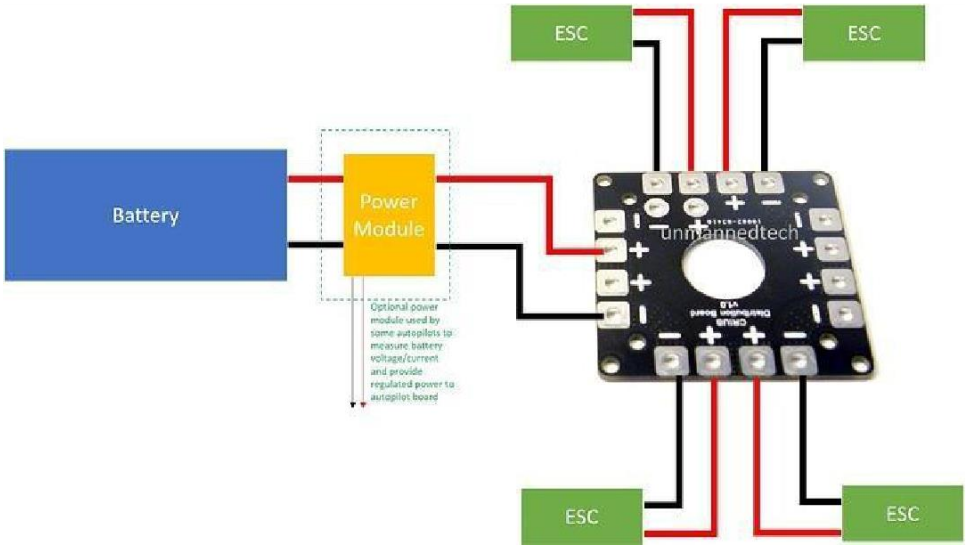
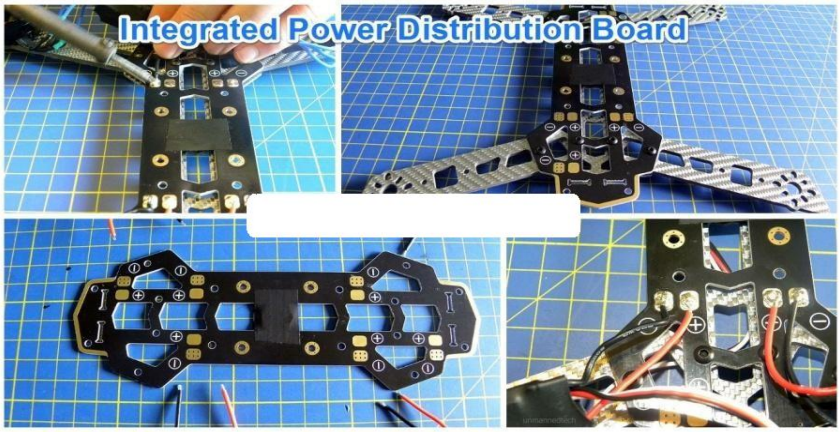


Figure: Power Distribution Board (PDB)

46.4.2. Stand alone or integrated PDB

Some multirotor frames has a power distribution board integrated into the frame, allowing us to solder the battery and ESC connectors directly onto the main frame of our drone which is very convenient. Integrated PDB boards can only be used with fibre glass plates, as carbon fiber conducts electricity, making it impossible to have a carbon fiber PDB. For this reason all carbon fiber quadcopters have a separate power distribution board which we mount onto our multirotor.



IID Training with Carbon fibre PCB

Figure: Integration in PDB

Some PDB boards also include a voltage regulator, also known as a Battery Eliminator Circuit (BEC). A voltage regulator is a small circuit that regulates the voltage to a specific value, commonly 5V, or 12V. So if we are using a 4S LiPo battery (which is 14.8V) the voltage regulator will convert that voltage and output a constant 12V, or 5V that we can use to power certain equipment such as LED lights, or FPV equipment which is a very useful feature. As not all equipment on our drone will be able to work on 14.8V. The PDB that is shown below 350 includes two voltage regulating circuits, one of them provides a constant 12V output, while the others is adjustable to whatever voltage we require.

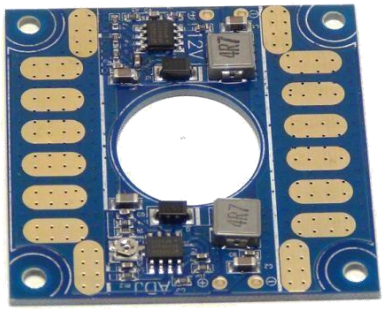


Figure: Power Distribution Board

46.4.3. How to choose a Power Distribution Board?

There are three main factors to be considered when it comes to choosing a PDB for our drone. Some multirotor frame kits include a PDB, or have one integrated inside one of the frame plates it's still a good idea to check the specs to ensure it will work with our motors/ESC as mentioned below.

46.4.3.1. Current Rating

The main safety aspect in terms of choosing a PDB for our drone is to make sure the PDB can handle the amount of current that is required to pass through it. The way to work this out is fairly easy, we simply need to check the ratings of our ESC's on our multicopter to find the maximum total current draw. So if we are building a quadcopter that uses 4x 20A ESC's we ideally need to have a PDB that can handle (4x20A) 80A. However in reality we will not be flying our quadcopter at maximum throttle, so we could get away with a 60A PDB, but in my opinion its always best to spend a bit more and use a over rated PDB as its worth the extra safety factor.

(i) Number of connectors: A fairly obvious thing to consider is to make sure the PDB has sufficient connectors for all of our ESC's so we can easily solder everything to our board.

(ii)Voltage Regulator: As mentioned before having a voltage regulator onboard the PDB provides a convenient way to power auxiliary equipment on our multirotor drone such as external LED's or FPV equipment.

46.5. Electronic Speed Controller

46.5.1. Definition

An electronic speed control follows a speed reference signal (derived from a throttle lever, joystick, or other manual input) and varies the switching rate of a network of field effect transistors (FETs). By adjusting the duty cycle or switching frequency of the transistors, the speed of the motor is changed. The rapid switching of the transistors is what causes the motor itself to emit its characteristic high-pitched whine, especially noticeable at lower speeds. Different types of speed controls are required for brushed DC motors and brushless DC motors.

- A brushed motor can have its speed controlled by varying the voltage on its armature. (Industrially, motors with electromagnetic field windings instead of permanent magnets can also have their speed controlled by adjusting the strength of the motor field current.).
- A brushless motor requires a different operating principle. The speed of the motor is varied by adjusting the timing of pulses of current delivered to the several windings of the motor.

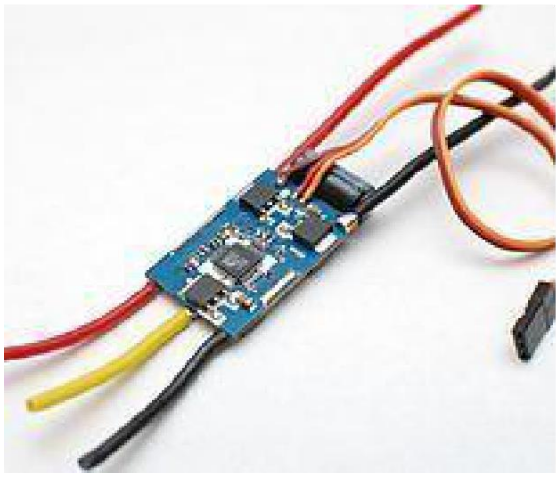


Figure: A generic ESC module rated at 35 amperes with an integrated BEC

Brushless ESC systems basically create three-phase AC power, as in a variable frequency drive , to run brushless motors. Brushless motors are popular with radio controlled airplane hobbyists because of their efficiency, power, longevity and light weight in comparison to traditional brushed motors. Brushless AC motor controllers are much more complicated than brushed motor controllers.

The correct phase varies with the motor rotation, which is to be taken into account by the ESC: Usually, back EMF from the motor is used to detect this rotation, but variations exist that use magnetic (Hall effect) or optical detectors. Computer-programmable speed controls generally have user-specified options which allow setting low voltage cut-off limits, timing, acceleration, braking and direction of rotation. Reversing the motor's direction may also be accomplished by switching any two of the three leads from the ESC to the motor.

46.5.1. Classification

ESCs are normally rated according to maximum current, for example, 25 Amperes or 25 A. Generally the higher the rating, the larger and heavier the ESC tends to be which is a factor when calculating mass and balance in airplanes. Many modern ESCs support nickel metal hydride, lithium ion polymer and lithium iron phosphate batteries with a range of input and cut-off voltages. The type of battery and number of cells connected is an important consideration when choosing a BEC, either built in the controller or as a stand-alone unit. A higher number of cells connected will result in a reduced power rating and therefore a lower number of servos supported by an integrated BEC, if it uses a linear voltage regulator. A well designed BEC using a switching regulator should not have a similar limitation.

46.5.2. Quad copters

Electronic Speed Controllers (ESC) are an essential component of modern quadcopter (and all Multirotors) that offer high power, high frequency, high resolution 3-phase AC power to the motors in an extremely compact miniature package. These craft depend entirely on the variable speed of the motors driving the propellers. This wide variation and fine RPM control in motor/prop speed gives all the control necessary for a quadcopter (and all Multirotors) to fly.

Quadcopter ESCs usually can use a faster update rate compared to the standard 50 Hz signal used in most other RC applications. A variety of ESC protocols beyond PWM are utilized for modern-day multirotors, including, Oneshot42, Oneshot125, Multishot, and DShot. DShot is a digital protocol that offers a certain advantage over classical analog control, such as higher resolution, CRC checksums, and a lack of oscillator drift (removing the need for calibration). Modern day ESCs protocols can communicate at speeds of 37.5KHz or greater, with DSHOT2400 frame only taking 6.5µs.

46.6. MOTOR

46.6.1. Definition

46.6.2. How to choose the right motor for our multicopter drone

Figure: Motors

To choose the right motor for our quadcopter or other multirotor, it would be desirable to have several test statistics at our disposal which can be found in the thrust data tables. which have carried these necessary tests, so we don't have to and these will provide us with the needed information. An example of one such thrust data table for a MT1806 is given below:

Motor Type	The Voltage (V)	Paddle Size	Current (A)	Thrust (G)	Power (W)	Efficiency (G/W)	Speed (RPM)
MT1806-2280KV	7.4	5030 Carbon Fibre prop	4.4	210	32.6	6.4	13530
		APC 6*4	6.8	280	50.3	5.6	12030
		5*4.5 Three-blade prop	6.2	240	45.9	5.2	12330
	11.1	5030 Carbon Fibre prop	8	380	88.8	4.3	18510
		APC 6*4	11.3	460	125.4	3.7	15160
		5*4.5 Three-blade prop	10.6	410	117.7	3.5	15910

Table: Thrust data for MT1806

If we are totally unfamiliar with brush-less motors, below are some details provided for your knowledge.

46.6.2. Analysis

Firstly, we need to analyze the weight of the multirotor. It is difficult to build / plan a drone by knowing exact weight. We need to analyze, what frame to be used. As frames are directly reflects on the weight of the motor, propeller size, camera and gimbal.

46.6.3. Thrust to weight ratio

With multi rotors it's important to make sure that our motors can produce around 50% more thrust than the total weight of our drone. Or in other words our drone should be able to hover at just over half throttle. This is an important rule to follow that motors will have enough extra thrust to control our multi-rotor in wind and during aggressive flight maneuvers. If we are always going to fly gently and smoothly by increasing the weight, so that we hover at around 70% throttle for a less.

responsive drone. So if our total weight of our quadcopter is 800g, our motors on a quadcopter will need to produce 1.6Kg of thrust in total, or 400g max thrust per motor.

For miniquad racing, we need an agile quadcopter, so that having a much higher thrust to weight ratio is desirable, but for an aerial photography drone that we will fly gently, we could get away with lower power to weight ratios, but in general I would say that we should plan to build at around a 2:1 power to weight ratio, as we can always use the extra remaining weight to add bigger batteries to fly for longer distance

Figure: Drone flying with 2:1 thrust and weight ration

Lets say we want to build the miniquad, Firstly we will start by deciding what frame we want to use?. If we use an 1806-2204 size motor, so by looking around on the internet we can get an average weight of this class of motors which is around 100g (which is actually a bit of over estimation). Simiarly 3-4S Lipo batteries that are around 1300-1800mah are commonly used with miniquads so we will base our battery weight on that size. The summary of the weight estimation is shown below, remember this is just a very rough estimate that we start with.

- Flight Controller - 15g
- R/C Receiver - 15g
- Frame - 150g
- 4x Motors and ESC - 200g
- 3S LiPo Battery (1300-1800mah) - 150g
- FPV Camera and Transmitter - 50g

So the weight of our drone will be around 680g so we need to have motors that can produce at least two times the amount of thrust in total (1.2Kg of thrust in total), however if they can produce more we will probably be able to fly faster. Since we are building a quadcopter, each motor must product at least 300g of thrust each.

If we do find this process particularly hard the best place to start is to look around a drone rest, or the internet for other drone pilots who have shared their information on a drone build similar to ours, we can then base our weights on the parts they used.

Based on our weight estimation we know we need to find a motor capable of producing a maximum thrust of 300g each, By inspecting the thrust tables of each motor we will gradual find a few motors that have the required thrust performance. In this case we have come across the data for the MT2204 motor which looks promising.

If we find it hard to know where to start, the best thing is to find a build guide, or quadcopter similar to the one we are building so see what motors and other equipment was used that we can use as a starting point.

The Voltage (V)	Paddle Size	Current (A)	Thrust (G)	Power (W)	Efficiency (G/W)	Speed (RPM)
8	Carbon Fiber Prop 6X3	6.4	240	51.2	4.7	11910
12	Carbon Fiber Prop 5X3	7.5	310	90.0	3.4	20100
	Carbon Fiber Prop 6X3	11.5	440	138.0	3.2	16300

Table: Thrust data for MT2204

46.6.4. Checking the thrust

Now we can get on with investigating and extracting useful information from a table such as the one above to find our quadcopter motor. We can see that this manufacturer has tested this motor with two different voltages (2S (approx. 8V) and 3S (approx. 12V) battery), and a number of different propellers (called paddles in the above table). We are then given the amperage that the motor pulls, the thrust that it produces and the efficiency (thrust in grams/power in watts), as well as some other information. We can see from the table that with a 3S battery, these motors will produce enough thrust with 5x3, or 6x3 propellers which produce more than the required 300g each.

46.6.5. Comparing the efficiency

Once we have found several motors that produce the required level of thrust an easy way to choose the best one would be to get the most efficient one, but this will also usually end up being the most expensive one.

Figure: A Drone Hovering Efficiency

However, as mentioned previously in this article, this may not be our priority. We may want small, agile copter for acrobatic moves in the air, in this case we need high rpm, and the efficiency will necessarily take a hit which is usually the case for high KV motors. In our example we are choosing a motor for a miniquad, so the type of motor we would use for these copters is one like the MT2204, the table of which is shown above. This is why the efficiency of this motor is relatively poor.

46.6.6. Matching an ESC to our motor

Now that we have confirmed that this motor is suitable for our application, we look at the Amp draw for our chosen motor/battery/propeller. In our case, this is maximum of 7.5A for a 5"x3" prop, and 11.5A for a 6x3 prop. Since in our build we chose 5"x3" propellers, so we need to use an ESC that is rated over 7.5A, so an 12A ESC would be a good choice for this motor/propeller running on a 3S battery.

46.6.7. Refine the weight estimate to choose a battery

Now that we have chosen some components, we will be able to update the initial weight estimate as we have actual weight of the components. Based on these motors producing a max thrust of 310g with 5x3 props, our quadcopter should weigh less than 620g. The actual weight of all the electronics and the quadcopter frame come to 368g, so that means we can get a battery up to

250g in weight. If we find that we don’t have enough weight left over for a decent size battery we might want to choose larger motors, or use larger propellers.

Instead of using heavy weight battery, i.e., try to use a slightly lighter battery at 160g (tattu 3S 1800mah) was used so that our quadcopter will have more agility for racing. The actual brand will depend on our preferences and budget, but for more information check LiPo battery buying guide.

46.7. Propellers

46.7.1. Quadcopter Propeller Introduction

The purpose of our quadcopter propellers is to generate thrust and torque to keep our drone flying, and to maneuver.

The upward thrust force generated by the propellers is usually measured in pounds or grams. To keep our drone flying at a hover, the upward thrust needs to equal the weight of our drone. The thrust to weight ratio TWR (thrust divided by weight), indicates how much thrust our drone generates relative to its weight. A good rule of thumb is to design the TWR to be at least a value of two.

Typically, quadcopter propellers produce more thrust the faster they spin. They are also influenced by the flight dynamics of our quadcopter. Some propellers produce much more thrust when the drone is stationary, as opposed to when it is flying. Other props perform much better at higher speeds.

Torque is generated when the propellers accelerate up or down. This force is responsible to check the drone ability of the drone to rotate on the yaw axis. Torque is an effect of Newton's third law, where every action has an equal and opposite reaction. As the propeller rotates, and pushes through the air, the air pushes back and causes a counter rotation on the body of the drone. This is why all the propellers on a multirotor drone do NOT rotate in the same direction (see below Figure). The counter rotation effect of all propellers cancels out, and we have no rotation. By changing the relative RPMs of the motors, we can cause a yaw rotation of the drone.

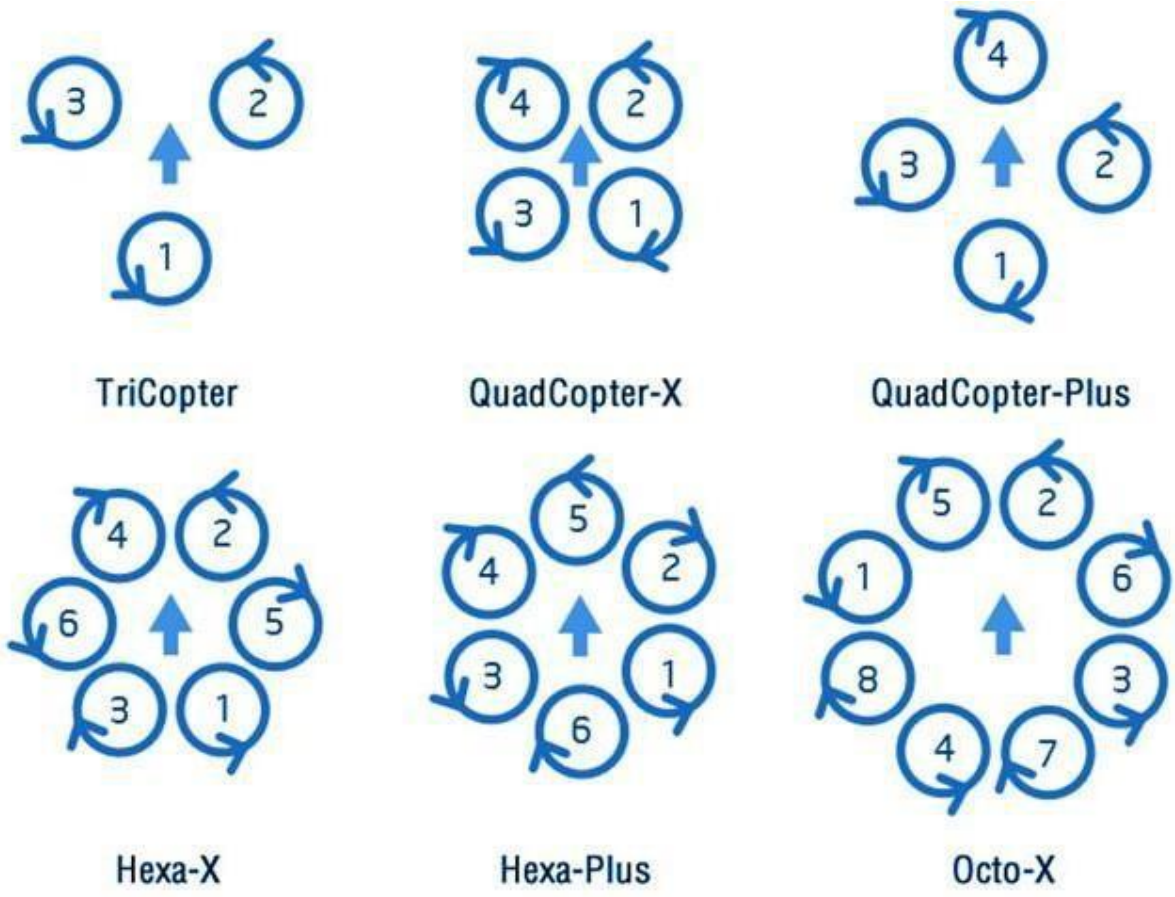


Figure. Multirotor Propeller Rotation

Our drone has two different types of propellers and motors. One set is designed to spin clockwise, while the other is designed to spin counter clockwise. Be sure to identify which ones are counter and anti-counter.

46.7.2. Quadcopter Propeller Pitch

The quadcopter propeller pitch is a measurement of how far that a propeller will move through the air for every single rotation of the motor/propeller. This is only a theoretical approximation since real world factors such as prop material, air density, and efficiency can influence this distance. However, the pitch is a good measurement which helps in better understand of the propeller performance.

The higher the pitch value, the faster our plane will go. To better understand the effect of propeller pitch, imagine two wood screws as shown in below Figure. The screw on the left has a coarse thread (higher pitch), and the screw on the right has a finer thread (lower pitch). If we were to take a screwdriver, and screwed both into a piece of wood and turn the screwdriver at the same speed for both screws, we would notice that the screw with the coarser thread (higher pitch), would sink into the wood more.

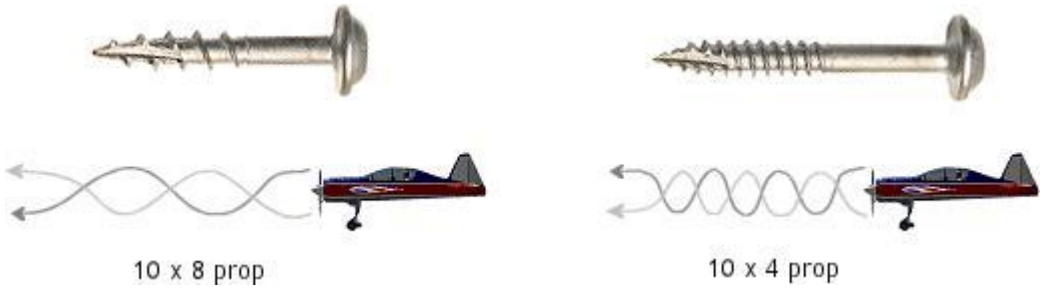


Figure. Propeller Pitch

This is the same effect as a propeller cutting through the air. In the figure, the two arrow lines show the position of the propeller tips. We can see that the high pitch propeller covers the same distance travelled with only half the rotation of the propeller. With both motors/propellers spinning at the same RPM, the higher pitch propeller will travel further in the same amount of time. In other words, the plane with the higher pitch propeller will fly faster.

Changing the propeller pitch will also change the dynamic response of our quadcopter. To produce the required thrust, a quadcopter propeller needs to be designed within a specific range of pitch angles. An almost flat propeller is as bad as a steep pitched propeller, that it will not generate any lift.

The flatter the blade, the easier it is for the motor to rotate the blade through the air. Toy grade or low-end quadcopters are equipped with low power motors. These motors need to spin faster to create lift, but higher RPMs are easier to generate with a smaller motor than torque.

46.7.3. Quadcopter Propeller Size

The size of the propeller is the distance from one end of the tip to another end of the tip. Longer propellers can generate more thrust at the same speed, but requires more torque from the motor to

turn the prop. A larger propeller size does not mean that we will be able to fly faster. That is mostly determined by the propeller pitch.

The surface area of the propeller also determines how much thrust it can generate. The higher surface area allows more air to be moved, thereby generating more thrust. This also comes at the cost of more power draw from the motor.

The length of our quadcopter frame determines the maximum size of propeller that we can use. This can easily be determined by taking the smallest of the length or width of our drone frame, and dividing by 2. Then we need to make this slightly smaller to provide rotation clearance between adjacent propellers.

For a square frame configuration (see below figure 1), the maximum propeller size is X/2. For a rectangular frame configuration (see below figure 2), we take the smallest of the length or width dimension, in this case it is obviously Y, and divide by two, that is Y/2.

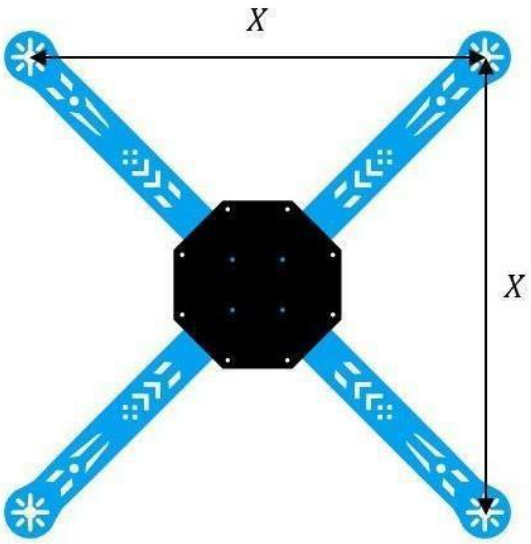


Figure 1. Frame and Prop Size

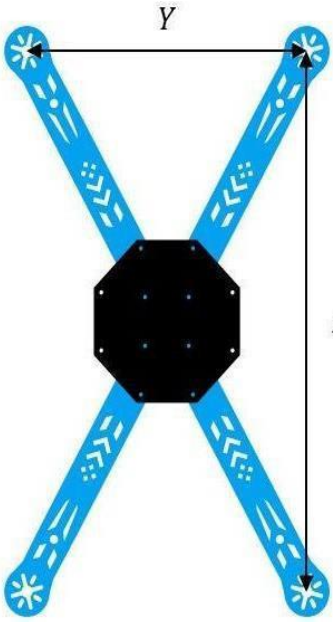


Figure 2. Minimum Frame and Prop Size

Overlapping the propellers is not recommended since the downward airflow of one quadcopter propeller will reduce the thrust efficiency of the propeller below. There is also a bit of side to side airflow due to tip vortices, so we want to allow for some spacing between the propellers to avoid this effect.

46.7.4. Number of Blades

Two bladed propellers are more efficient at producing thrust as opposed to three or four bladed propellers (see below Figure) so long as the tips do not reach supersonic speeds. For the purposes of quadcopter propellers, this is not a problem.

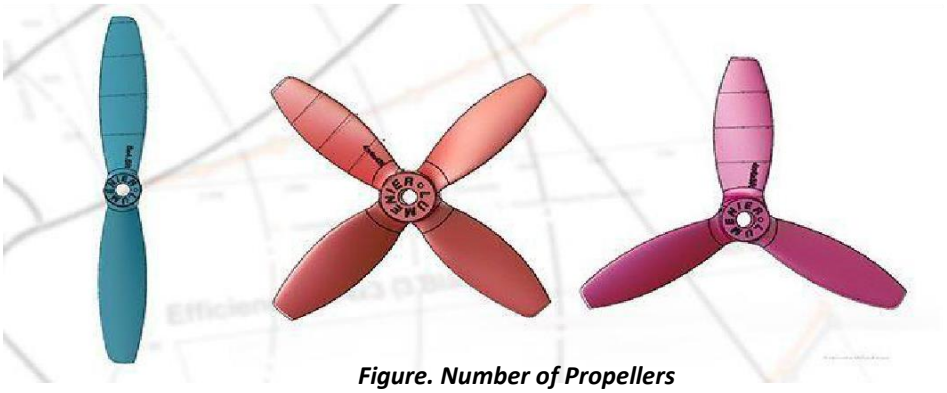


Figure. Number of Propellers

Adding blades increases the amount of thrust that is generated, but at the cost of efficiency. We will see many drones that have 5-inch triple blade propellers. The aerodynamic environment of drones negates the inefficiencies of tri-blades in the 5-inch size. Tri blades also have a higher torque generation which makes the yaw axis of the quadcopter much more responsive. There are 4, 5, and even 6 blade designs, but these have diminishing returns due to inefficiency.

46.7.5. Propeller Material

Propellers are usually made from a plastic compound, though carbon fiber propellers are also available. The type of material used to make the quadcopter propeller affect its stiffness and durability.

Most hobby drone pilots are using durable plastic propellers that are slightly flexible and bend when our drone crashes. This allows them to last much longer, and save we money in the long run. These propellers have a disadvantage of causing vibration as they rotate, which can affect the flight performance of our drone.

Carbon fiber propellers have a number of advantages, and disadvantages. They produce less vibration due to their stiffness, and sound quieter when flying. They are much lighter, and are stronger than plastic propellers. However, they are expensive, and the inflexibility means the motor bearings will take the brunt of the impact force on crashes.

46.7.6. Propeller Weight

For better flight performance, we choose lighter propellers compared to heavier ones. Lighter props have less moment of inertia, which means the motor needs to apply less torque to generate the same RPM. This also results in faster RPM changes which leads to better drone flight response. The weight distribution greatly affects the amount of vibration that the propeller will generate. A perfectly balanced prop will produce no vibration, while an unbalanced prop will affect the flight performance, and also makes more sound.

46.7.7. Bull-Nose Propellers

The more surface area that a propeller has, the more air it can push thereby creating more thrust. The downside is higher current draw, increased drag, and reduced power efficiency. Bull nose propellers are more commonly being used on modern quad copters (see below Figure)

Figure. Bull Nose Propeller

Bull-nose quadcopter propellers have a greater surface area, and create more thrust. Tapered propellers create less tip vortices, but sacrifices thrust as the propeller gets thinner. These are better suited for slow moving quad copters where stability is more important for applications such as aerial photography.

The added surface area of the bull-nose propeller means that we are adding weight, especially further away from the hub. This increases the moment of inertia of the propeller, and requires the motor to apply more torque, drawing more power from the battery. Bull-nose propellers are commonly used on small racing frames to gain a higher thrust at a smaller size.

46.7.8. Quadcopter Propeller Sizing

When selecting propeller sizing we need to understand the format that manufacturers use.

There are two common formats that are used: LxPxB or LLPPxB.

L represents the length, P is the pitch, and B is the number of blades. We may also see a BN designation that stands for bull-nose.

We may also see an R or a C after the sizing numbers. The R stands for reversed, which is the rotation direction of the propeller. An R propeller needs to be mounted on a drone motor that rotates clockwise. A propeller with a C designation is to be mounted on a motor that rotates counter-clockwise.

46.7.9. Folding Propellers

There are many drones that are designed to highly portable, so we can easily take them anywhere along with us. To accomplish this, foldable propellers are included in the design (see below Figures).

Figure 1. Foldable Propellers

Figure 2. Foldable Propellers

At the high RPMs needed to generate lift to fly our drone, the outward force due to the motor rotation is sufficient to keep the propeller in its proper position. So, when we take off and jam the throttle on high, we can be sure that our drone will fly. The foldable propellers are designed to maintain balance, so we do not lose any thrust generation efficiency.

There is a slight advantage that a foldable propeller has that a fixed prop doesn't. On a fixed prop, when we push the throttle to high, all the motor torque is transferred to the propellers. With a foldable propeller, there is a bit of an absorbing effect that helps to cushion the impact on our drone. This will quickly balance out and the full torque will be applied to the propeller. The cushioning effect is beneficial to reduce shock impact on the camera.

46.7.10. Propeller Damage

If our quadcopter has crashed, Firstly, we careful need to look at the propellers for any damage. A few scrapes on the propeller are ok, but flying with nicked propellers will make it nosier, and increase vibration. This will have the effect of shortening the life of the motors, since the bearings will rotate as if they are unbalanced.

The quickest way to check for any damage is to run our fingers along the leading edge of the propeller. If we feel any major nicks, then it's time to replace the propeller. Be sure to keep a few extra propellers on hand if they need to be replaced. Most quadcopters that we buy come with extra propellers. Remember, that there are two different directions that the propeller can rotate (see previous section). Be sure that we are mounting the correct propeller on the right motor.

46.7.11. Propeller Thrust and Speed

To know how much thrust a given propeller will produce, we must examine motor thrust test data which most manufacturers provide. The same propeller on two different motors can have vastly different performance due to variances in design, torque, power, and RPM.

However, these bench tests are done in a static environment, and do not reflect the actual environment when our quadcopter is flying. Typically, we can expect to see 5 to 10% less thrust in real flight as compared to the bench tests. We need to consider this into account, when we are sizing our propeller and drone motor.

46.8. LITHIUM POLYMER ION BATTERY - LIPO

Batteries are the main power source for UAVs and it is Important to understand the below points.

Figure: LIPO Battery Description

- There will be some fuel engine based UAV technologies but they will be expensive, heavily regulated and application specific.
- At least ninety percent of public, hobby and civilian UAVs will be powered by some kind of battery.
- Nickle Cadmium (NiCad) and Nickle Metal Hydrid (NiMH) were first used, but Lithium based batteries have now taken over.
- The reason for the popularity of lithium batteries is simple - really high energy density.
- Lithium batteries have enough stored energy to let our UAVs fly for at least a useful length of time.
- The current rating of a battery refers the total energy available from the battery at its rated voltage.
- Assuming cells are only in series connection and not parallel connection and the current rating is also the same as for each individual cell.
- The rating is in mAh (milliamp hours) and is the available current that can be provided by the battery for one continuous hour.
- For example a 1000 milliamp hour (1 Amp Hour) battery may be discharged at 1 Amp for 1 hour.
- Batteries are composed of a series of cells from one to several and it may be in series or parallel connection.
- Individual cells or a single cell battery in Lithium Ion or LiPoly is anywhere from 3.2 to
- 3.7 volts depending on chemistry.
- Although cell voltage remains identical for a given chemistry current capacity of cells can be different.
- All cells in a given battery will, however, have the same current capacity.
- If two cells are connected in series (positive to negative) voltage will double but current capacity will stay the same.

- Two cells in parallel (positive to positive and negative to negative) doubles current capacity but voltage stays the same.

- The batteries we use are usually a set of cells of the current capacity we need wired in series to produce the voltage we need.

- For Example a LiPo 3S1P designation refers to three 3.7 volt LiPo cells in series producing a nominal 11.1 volts.

- It is possible to combine two or more batteries in parallel to double or further increase our total energy capacity.
- It is also possible to combine two or more batteries in series to double or further increase the voltage.

10.1 When combining batteries in parallel (or series) they must have identical characteristics (voltage and current capacity).

10.2 For Lithium Ion we may make a battery with series and parallel cell interconnection for both the voltage and current we need.

46.8.1. Battery Safety

- A battery's C (capacity) rating is the maximum safe continuous discharge rate of a battery.

- A batteries maximum acceptable discharge rate is calculated by multiplying its current rating by its C rating.

- A C rating of 1 means the battery can be discharged at the same rate as its capacity.
- So a 1 Amp (1000mah) battery with a C rating of 1 can be continuously discharged at 1 Amp.

- A more typical example: 11.1 volt 2000mAh (2 amp) battery rated at 10C = 2 Amps x 10C = 20 amps continuous discharge.

- We use the C rating to determine if a given battery has sufficient current available to drive our motor(s) at maximum output.

- Exceeding the C rating for a significant period will result in damage to the battery and can cause it to burn or even explode.

- Batteries also often indicate a second (safe) short term maximum C rating (commonly 50% over the continuous C rating).
- A typical LiPo battery rated at 3S1P 10,000mAh 20C can be broken down as follows:

- 3S1P means 3 cells in series none in parallel, since individual cells are 3.7 volts, the battery is 11 volts.

- 10,000mAh means since the cells are only in series each 3.7 volt cell has 10,000mAh or 10 Amp Hours of capacity.

- The 20C rating means the Battery can be discharged at a rate 20 times its 10 Amp hour capacity up to 200 Amps continuously.

46.8.2. Lithium Battery Types

Figure: Types of LIPO Batteries

There are lithium ion (Li-ion), lithium iron phoshate (LiFePO4), lithium polymer (LiPo) and lithium titanate batteries. All lithium batteries are in fact a type of lithium ion battery, not just the ones we call lithium ion. Lithium ions move from a negative electrode through a semi permeable membrane to a positive electrode to supply power.

The process is reversed when the lithium battery is being recharged. There are a variety of lithium chemistries and each has its good and bad Pros and Cons.

LiCoO2 Lithium Cobalt Oxide has a high energy density but it has a low discharge rate and is

a flammable safety hazard. LiCoO2 are more prevalent Lithium Ion batteries but lithium manganese oxide (LMO) are in common. Generally, lithium ion batteries are in a cylindrical configuration in a metal can.

The Panasonic NCR-18650 and its clones are the most commonly available Lithium Ion batteries. The Panasonic and most other Lithium Ion batteries now include internal short circuit and overload protection. LiFePO4 Lithium Iron Phosphate has a lower energy density, but is safer, has a higher discharge rate and a longer lifetime. LiFePO4 have become popular for RC transmitters, more capacity than NiMH batteries and faster charging. They are occasionally used in planes but are heavier than other lithium batteries with equivalent capacity.

LiPo Lithium Polymer batteries are flat packs with a polymer separator with higher discharge rates and lower energy density. LiPo batteries use normal lithium ion chemistries, the polymer separators reduce capacity but permit higher discharge rates. Changing the physical and chemical nature of the separators, anode and cathode allow specific features to be optimized. LiPo batteries are currently most commonly used for UAV but Lithium Ion has capabilites we need to consider.

Lithium Ion and Lithium Polymer Battery Energy Densities

Battery & Link to Information Used	Volts (VDC)	Capacity (mAh)	Mass (g)	Energy Capacity (WH)	Energy Density (Wh/kg)
Panasonic NCR 18650B Lithium Ion	3.6	3.2	0.047	11.52	245.11
Zippy Flight Max Lithium Polymer	22.2	5	0.703	111	157.89
MaxAmps MA6S11000 Lithium Polymer	22.2	11	1.235	244.2	197.73
MaxAmps MV5450 Lithium Polymer	3.7	5.4	0.131	19.98	152.52

Table: The Above table shows the comparative energy densities of various popular batteries.

Above table shows energy density per unit weight of the battery and is what we should use for comparison. The following comparisons are based on the weight of the various batteries being the same - the capacity will vary.

The Panasonic Lithium Ion battery has almost twice the energy density of an average (Zippy) Lithium Polymer battery. The Panasonic supplies at least 25 percent more than a top of the line Max Amp Lithium Polymer battery.

The Zippy Compact Pro LiPo battery performance is representative of the majority of batteries in common use in our UAVs. Substituting a premium battery like the Max Amp can directly result in 25 percent longer flight times for equal battery weight. And if we can accomodate the Panasonic Lithium Ion batteries slow discharge rate we can nearly double our flight times.

46.8.3. Lithium Polymer

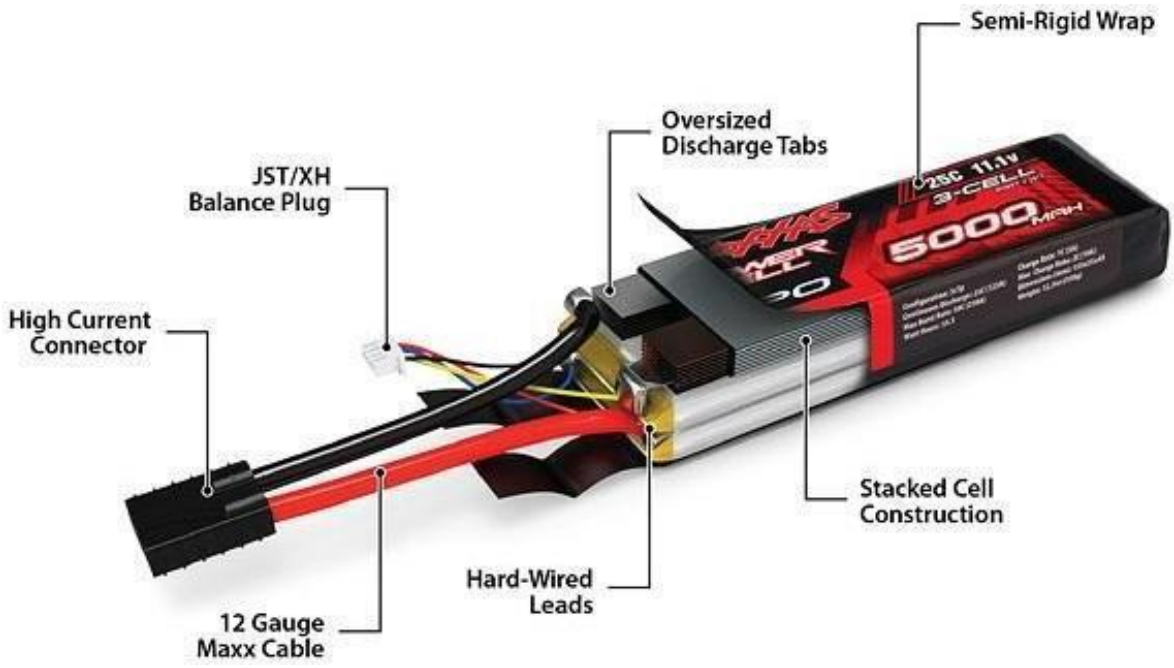


Figure: LIPO Polymer Battery

12. The Lithium Polymer battery is popular because it has a high discharge rate, and the square package fits in our UAVs.

13. The above cut away shows how the individual cells are stacked and wired and how the balance plug is connected to each cell.

14. To achieve equal energy capacity, each cell needs to be voltage matched to the other using the balance plug during charging.

15. LiPos batteries are readily available in a wide variety of sizes: Milliamp Hours per cell and Number of cells

16. For our UAV use two cells to 6 cells in series and 100 to 10,000 milliamp hours are commonly available.

17. Claimed life span is 600 nominal discharge cycles although reality for most is probably more like 300.

18. Failure mode can be simple exhaustion, but "puffed" cells that have failed internally and are common.

19. LiPo batteries can also fail catastrophically from external or internal short circuit or from physical damage and burn vigorously.

20. They can even burn up while just sitting there not doing anything at all, although fortunately this is less common now.

21. The energy density available in LiPos can permit flights from 10 to 30 minutes in copters and perhaps up to an hour on airplanes.

46.8.4. Lithium Ion

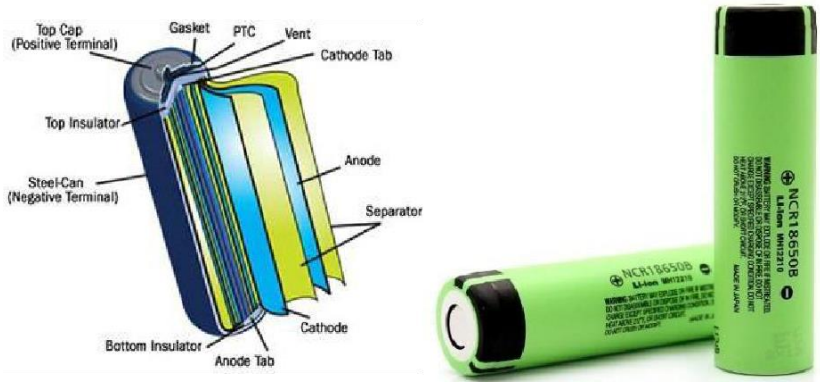


Figure: Lithim ION Battery

- Lithium Ion batteries can have one major advantage, up to twice the energy density of a LiPo.
- They are always cylindrical and generally have a metal casing giving up some space and weight, but not much.
- Even with those constraints Lithium Ion batteries normally have at least 70 percent more energy density by weight than LiPos.
- This directly translates to 70 percent longer flight time (if we can use them).
- The Achilles heel of the Lithium battery for our use is it's low discharge rate.
- Current Lithium Ion batteries have a 2C Discharge rate and if we drain them above that rate it will damage the battery.
- In fact many of the popular Lithium Ion batteries now include built in protection against charging or discharging too fast.
- But for our use this only means that if we need more power than the battery is rated for it simply won't provide it.
- If we are flying a multicopter and a motor needs to speed up for stability and the power is not available we have a problem.
- Or if our airplane needs more power than is available, it can pull down the electronics and servos to where they won't function.
- Nonetheless, the high energy density definitely justifies designing UAVs that can work within the Li Ion discharge envelope.
- A properly designed copter could get 40 to 60 minute flight times and an airplane up to two hours with lithium ion batteries.
- A secondary advantage of lithium ion batteries is that they can operate to over a thousand charge cycles if properly cared for.
- The NCR-18650 Lithium Ion Battery pioneered by Panasonic is available in a variety of single cell energy capacities.

Since lithium ion batteries come as single cells we will need to either "spot weld" several together with tabs or use a holder

46.8.5. GEB 8043125

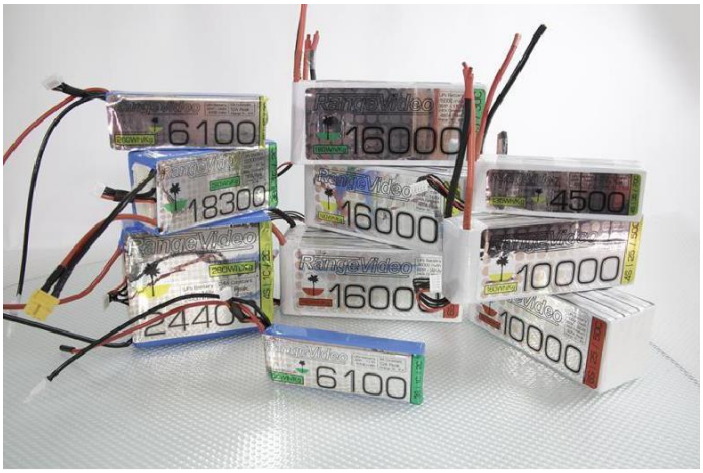


Figure: Lithium ION Batteries

There is at least one flat pack style battery claiming equal capability with the Lithium Ion the GEB 8043125.

- The GEB 8043125 seems to have demonstrated an energy density rivaling a standard cylindrical lithium ion battery.
- So far there have been results that seem to corroborate the performance claims but there is a down side.
- Capacity begins to drop around 50 cycles so cylindrical li-Ions like the 18650 or regular LiPos are better for normal use.
- The Battery below left weighs 765 grams and has 18,300mAh 3S3P with a 2C discharge rate of 36 amps at 11 volts.

Figure: 18,300mAh Battery

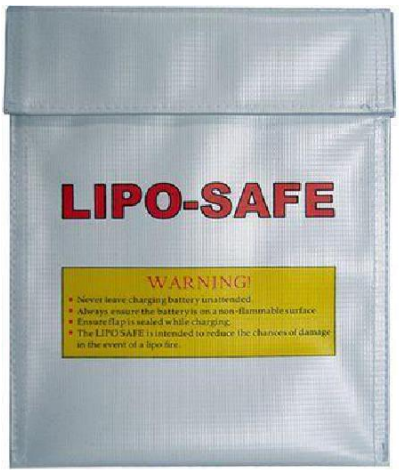


Figure: Lipo battery Pouch

46.8.6. Lithium Battery Safety

Using Lithium Batteries Safely is Extremely Important as they can easily catch fire or even explode.

- Lithium batteries need special handling because physical damage or short circuiting them is likely to cause them to catch fire.

- Store them in a special bag (above right) when not in use or while charging and keep the bag where it could contain a fire.
- If a LiPo pack starts to expand (puff up) or if it won't take a full charge on all cells, dispose of it.
- Before disposal a LiPo battery should be discharged by connecting it to a resistive load (light bulb or charger-discharge function).
- It is a good idea to keep a metal bucket filled with sand handy in case a LiPo fire needs to be quenched.
- DO NOT put water on a burning LiPo Battery, lithium takes oxygen directly out of water and keeps on burning.
- Lithium batteries are likely to misbehave while charging or discharging or when dropped.
- Although Lithium Ion batteries have more energy and are also safer due to internal overload protection and steel case.

46.8.7. Battery Chargers

Figure: Lithium Battery Charger

All Lithium batteries require tightly controlled charging methods and a quality charger is very important.

- Never charge, discharge, use, or store a damaged or puffy LiPo battery. Immediately follow proper disposal protocols.
- Avoid purchasing used LiPo batteries. We never know what the previous owner did with them and they could already be badly damaged. “LiPo Battery Like New, Used Once” is usually a scam and should be avoided.
- Always use a proper LiPo battery balance charger/discharger when charging and discharging our LiPos. It is crucial that all cells in a LiPo battery maintain the same voltage across all cells at all times. If the voltages across the cells deviate too much from each other (5mV ~ 10Mv), the battery can become unstable and dangerous. (Unless it’s a single cell LiPo, in which case we do not need to worry about cell balance).
- Always use a fire proof LiPo safety bag, metal ammo box, or other fire proof container when we are charging, discharging, or storing our LiPo batteries. Lipo rarely catches fire. If it catches fire it will quickly causes lot of damage. All it takes is an internal short circuit to set the battery off. There is no way to predict when it will happen. It does tend to happen more often when batteries

are fully charged, being overcharged, or while being discharged, but it can happen to any LiPo at any time. Never fill the container to capacity with our batteries, always follow manufacturer recommendations on LiPo bags for how many mAh's it can safely contain. It's ALWAYS worth investing on LiPo bag for carrying a battery.

- Do not use our flight case/travel case for long term LiPo storage. The foam and plastic in these cases can help spread a LiPo fire. Always use a fire proof container such as a metal ammo box or fire proof safe for storage.

Never leave LiPo batteries charging while unattended. If a battery starts to become puffy, smoke, or catches fire we need to handle the situation immediately. Walking away for even just 5 minutes can spell disaster.

- A LiPo fire is a chemical fire. Always keep a Class D fire extinguisher nearby our battery charging/discharging and storage area. The battery charging/discharging and storage area should be free from any materials which can catch fire such as wood tables, carpet, or gasoline containers. The ideal surface for charging and storing LiPo batteries is concrete or ceramic.

- Never overcharge a LiPo battery. Typically a full charge is 4.2v per cell. Never "trickle" charge a LiPo battery.

- Never discharge a LiPo battery below 3.0v per cell. Ideally we never want to go below 3.2v per cell to maintain a healthy battery. 2.9v per cell and lower is causing permanent damage.

- Never leave our LiPo batteries sitting around on a full charge for more than 2-3 days. On the 3rd day we realize we are not going to use our battery today, we need to discharge our battery down to 3.6v-3.8v per cell for safe storage until we are ready to use the battery again.

- Always store our LiPo batteries at room temperature. Do not store them in a hot garage, or in a cold refrigerator. Even though a cold battery has less chemical reaction taking place which can prolong its lifespan, taking a battery out from a cold fridge can cause condensation to occur on the inside of the battery, which can be very dangerous.

- Always remember that heat is the number one enemy of LiPo batteries. The hotter our batteries get, the shorter their lifespan will be. Never charge a battery that is still warm from usage, and never use a battery that is still warm from charging.

- Depending on how they are used, most LiPo batteries typically do not last longer than 300 charge cycles. Leaving them around on a full or depleted charge all the time, running them completely dead, or exposing them to high temperatures will shorten this lifespan dramatically.

46.9. Charger / Voltage Checker

Figure: Drone Battery Charger

46.9.1. Everything we need to know about drone chargers

Drones are trending everywhere, their videos, their pictures and regulations everything is in the news. Only a drone fanatic knows the feeling of owning one! But with drone comes a lot of care and accessories, battery chargers, the case, and the gimbals and the propellers.

46.9.2. What is a good drone charger?

Drone batteries need a good compatible charger that defines it longevity and performance, hence selection of a good drone charger is important.

Many brands have proprietor batteries that are compatible with the drone, hence these brands have their own compatible battery chargers. Usually, these chargers take a lot of time in charging the batteries. Hence switching to a different charger is not an issue but make sure to check the compatibility of the charger and the battery.

46.9.3. What all kind of chargers are in the market?

There is a flourishing market of drones which is all set to offer us all kinds of drones and their accessories, the task is to know which one is the best.

There are a plethora of options for us to choose from but we have to go for the one that is compatible with our drone batteries, safe to use, easy to carry around and that enhance our battery life.

46.9.4. Quick Checklist- Things To Keep In Mind Before Buying A Drone Charger

46.9.4(i) Balance Charging

It is a process which checks the voltage of each cell and then maintains the voltage while charging. This is one critical point, to take care because if the required voltage drops or fluctuates then the batteries can get damaged or they can even catch fire.

The good part is that the majority of the charger has balanced charging, so if our battery before charging wants balance lead to be plugged in then it assures of the balance charging function. If we directly connect the charger then there might be a chance that our charger has doesn't have the balance charging ability.

46.9.4(ii) Cell Compatibility

When buying a charger for the first time, we would suggest to check the compatibility of the charger with the batteries. Some cheap lipo charger support 2S or 3S lipo, whereas some fancy chargers might offer a range of 1S-6S lipo.

46.9.4.(iii) Current Rate

Most batteries will specify the charge rate in C rating, but what happens, some of the chargers specify the charge rate in Amps, which sometimes leads to confusion between two values. No need to worry, we just need to multiply our battery capacity with C rating to get the value in Amps.

For Example

Battery Capacity - 5100mAH;

Charge Capacity - 1C

So the maximum current we need to charge the battery will be -
5.1Ah x 1= 5.1A

46.9.4(iv) Power output

There is a certain power output level, approximately 50W. This number basically represents the power which it can provide to the battery. Hence having more power is better!

46.9.5(iii) Power supply

Most of the batteries have an inbuilt power supply, but for the ones which do not have this inbuilt feature then we have to match this with our charger.

46.9.5(iv) How and How's?

(A) How to charge our Drone Batteries?

- Plug the charger and the balance leads, between our battery and charger
- Select the needed LiPo balance charge
- Select the needed cell count voltage (recommended 1C)
- Start, and make sure we don't leave it unattended.

(B)How To Store Batteries & Charger Properly?

- The best way to store our battery is when it is 40-50% charged.
- **Lipo Safe Bag** - These bags are an added accessory that we must want to have, in order to keep fire away.

(C) How To Charge LiPo Batteries?

- Do not leave our battery on charge unattended
- Do not charge a damaged battery
- Always charge our battery at 1C or less

- Charge our batteries in a fire proof location or in lipo safe bags
- Ensure the number of cells and battery type is set correctly.

46.9.5(v) Battery Safety Tips

Now we know how to use our LiPo battery, we'll look at some safety tips we need to follow. It seems like quite an obvious tip but don't use a battery with any known or visible damage including leaking and swelling. It could result in a drone crash or even worse and is simply not worth to take the risk. A new battery is a fraction of the cost for the drone, so just don't risk it. If our battery comes into contact with water, stop using it immediately. Allow the battery to dry in an open area then dispose of it following the below advice in the 'Battery Disposal' section. We should also keep in mind weather conditions such as fog and mist can result in water on our aircraft and batteries, so we need to take care of it.

If a battery ever catches fire, do not use water to put it out as this made spread the fire. Use sand or fire extinguisher designed for electrical fires.

46.9.5(vi) Battery Charging

Charging our battery is a large part of battery care. Make sure that we follow the below tips.

(i) Only use an official charger for our battery. We may be able to find cheaper versions online, but third-party chargers don't go through the same rigorous testing as that of the manufacturer. We will also likely void our warranty so if we encounter any issues, we won't be covered.

(ii) Each different aircraft battery type has different temperatures we can charge them between. We will be able to find this in the user manual for our aircraft/battery. A general rule to follow is to charge at room temperature between 22 to 28°C.

(iii) Don't charge the battery straight after flying. Wait around 15 minutes to let the battery cool down before charging. DJI Intelligent Flight Batteries have four LEDs to show the amount of charge in a battery. The below chart shows the meaning of the LEDs and the amount of charge in the drone battery.

LED1	LED2	LED3	LED4	Battery Level
●	●	○	○	0% - 50%
●	●	●	○	50% - 75%
●	●	●	●	75% - 100%
○	○	○	○	Fully Charged

Table: Battery Charge Level using LED

46.9.5(vii) Intelligent Flight Battery LEDs

Further to the LED charge status, DJI Intelligent Flight Batteries LEDs provide updates on the health of the batteries including charging temperature, short circuit detection, overcharge detection etc. This will appear when charging the battery and should be used as instructed in a guide.

Battery Level Indicators for Battery Protection

LED1	LED2	LED3	LED4	Blinking Pattern	Battery Protection Item
○	●	○	○	LED2 blinks twice per second	Over current detected
○	●	○	○	LED2 blinks three times per second	Short circuit detected
○	○	●	○	LED3 blinks twice per second	Over charge detected
○	○	●	○	LED3 blinks three times per second	Over-voltage charger detected
○	○	○	●	LED4 blinks twice per second	Charging temperature is too low (<0°C)
○	○	○	●	LED4 blinks three times per second	Charging temperature is too high (>40°C)

Table: Battery level indication for battery protection

46.9.5(viii) Intelligent Flight Battery LED Meanings

Never leave a charger unsupervised, especially overnight or when you are out of the house. Although charging is significantly safer than it used to be, we should monitor the battery periodically just to be safe.

Never charge our battery on a flammable surface. We can use a metal box or fireproof bag during charging.

Finally, once a battery is fully charged, remove it from the charger. Intelligent Flight Batteries do have overcharge protection. However, this will give us an additional protection when charging.

46.10. Bullet connectors

Always prefer to use bullet connectors between motor and ESC. Lots of folks use solder on these joints for a very good reason. One loose connection on a multirotor motor circuit can spell disaster. In addition to the possibility of a loose connection, it is often the case that the heat shrink insulation can leave a small gap between the two parts of the bullet. I want all my electrons to stay where they belong :

So here is a solution to both issues:

- Break out the manual 3D printer(hot glue gun)
- Cut out a piece of silicone sheet to use as an ad-hoc mold
- Apply a small bead of the glue and use the silicon to shape a thin film evenly around the joint
- Peels off cleanly when we need to break the connection.

Figure: Bullet Connectors

46.11. Soldering gun

Soldering is an essential skill in building and repairing a quadcopter, RC plane and mini quad (commonly known as racing drones). Soldering is basically joining multiple conductive metal parts together by melting and flowing solder between the joint.

Soldering takes practice and could be hard at first, but it's going to be one of the most useful skills that we learn by practicing. It enables us to do other electronics projects and even fix simple electrical devices in the house .

46.11.1. Tools for Good Soldering

Getting good soldering equipment is just as important as acquiring good soldering skills. The tools that we would normally need for basic soldering jobs are:

- Soldering iron / Soldering station
- Solder
- Solder Paste / Flux
- Solder Helping Hand (third hand)
- De-solder wick / solder sucker Soldering Iron

Figure: Soldering iron with temperature control

A good soldering iron makes soldering easier. When choosing a soldering iron we need to consider:

δ) Is the iron temperature adjustable?
ε) What is the temperature range?
ϕ) Rated wattage

Adjustable temperature allows us to handle work better at different natures. For delicate soldering like working on small copper pads on the flight controller, we might want to lower the temperate to avoid damage to the board. When soldering large gauge wires or PDB, we will need higher temperature in order to heat up the large volume of metal more quickly. Having temperature range between 300°C to 400°C is important for our application.

The wattage of a soldering iron usually indicates how much heat it's able put out. Higher wattage irons are usually better at "heavy duty" soldering, because it's capable of heating up metal faster without too much temperature drop.

46.12. Circuit diagram for a Quadcopter

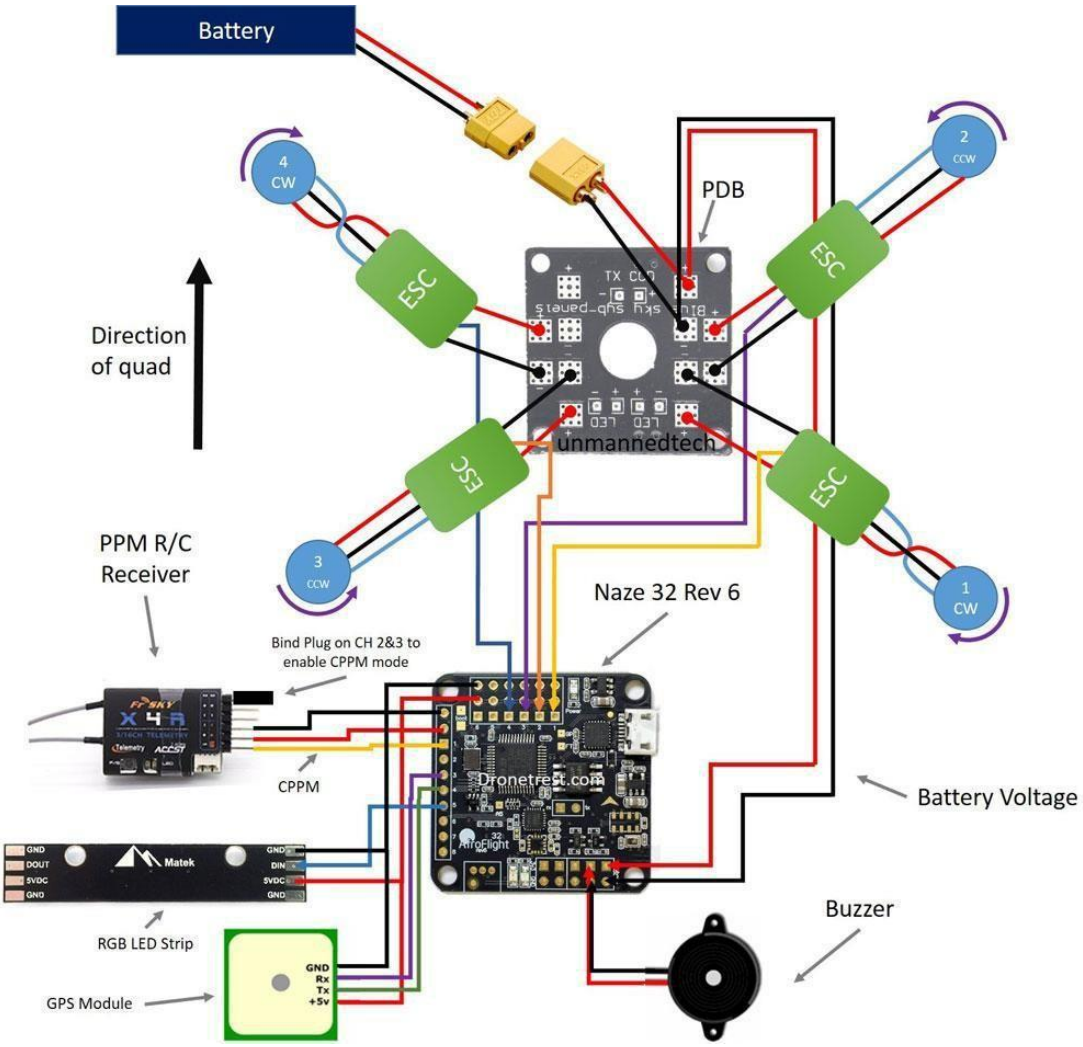


Figure: Circuit diagram for Quadcoptor

46.13. Model calculation

Sample calculation for making a Drone

Example:

Range = 1 km

Payload = 5kg

Endurance = 18 min

Let us assume body(frame) weight without payload

Weight to thrust ratio

Overall takeoff weight

Thrust required

Motors required = 3kg

So, Thrust of each motor

- 5kg + 3kg = 8kg

= 1:2.5

= 8:20

= 20kgs

= 6 no's

= 20/6

= 3.3kgs

	RPM/V (KV)	Stator Dia (mm)	Stator Length (mm)	Shaft Dia (mm)	Motor Dimension (Dia.*Len)	Weight (g)	Bullet connector	No/Load (10) @10v (A)	No.of Cells (LiPo)	Constant Current [A]	Max Burst Current (15s)[A]	Max Power (watt) (15s)	Max Thrust (KG)
AT2216	1250	22	16	3	27.8x34	68	w/3.5	0.6	2-4S	27	40	450	1.2-1.5
AT2814	1000	28	14	4	35x36	103	w/3.5	1.1	3-6S	40	60	700	2-2.3
AT2820	830	28	20	5	35x42	132	w/3.5	1.1	3-6S	43	70	800	2.8-3.0
AT2826	550	28	26	5	35x48	169	w/3.5	0.7	3-6S	48	75	1000	3.2-3.5
AT2826	900	28	26	5	35x48	167	w/3.5	1.6	3-6S	53	75	880	3.2-3.5
AT3520	730	35	20	5	43*45	206	w/4.0	0.8	3-6S	60	85	1200	3.8-4.2
AT3520	880	35	20	5	43*45	207	w/4.0	1.2	3-6S	60	85	1300	3.8-4.2
AT3530	570	35	30	6	43*55	288	w/4.0	0.9	3-6S	65	90	1800	4.5-4.8
AT3530	700	35	30	6	43*55	289	w/4.0	1.5	3-6S	70	90	1900	4.5-4.8
AT4120	550	41	20	6	49.5*49	286	w/4.0	1.3	4-8S	70	90	2100	4.8-5
AT4130	275	41	30	6	49.5*59	387	w/4.0	0.5	6-10S	75	95	2800	5.5-6.3
AT5330	190	53	30	8	63*63	635	w/o	1.4	6-12S	80	120	4500	8.0-10.0
AT2202	2300	22	2	3	27x18	14	w/o	0.3	1S-3S	6	11	90	250-280G
AT2204	1850	22	4	3	27x20	20	w/o	0.2	1S-3S	7	14	120	320-350G
AT2206	1500	22	6	3	27x22	25	w/o	0.2	1S-3S	10	20	200	400-500G

Table: Motor Selection

Refer to the above table, We have to choose the require RPM for that thrust.

AT2826 RPM - 550kv BLDC motor

Constant element of the motor is = 48A

Assuming voltage required = 22.2v

Power at 30% of constant current = 0.3 x 48 x 22.2

Power = 319.68 w

Total power required for 6 motors = 6 x 319.68 = 1,918.08 w

Assuming required flight time = 18 mins

Total energy for flight = flight time x power

= F.T X P

$$= \frac{18 \text{ X } 1{,}918.08 \text{ W}}{60}$$

Energy = 575.42 wh

Efficiency = 75%

Energy of the battery = Energy

$$\frac{\text{[redacted]}}{\text{Efficiency}}$$

= 575.42/0.75

= 767.23 Wh

Milli Ampere hour required = $E_{battery} / V_{battery}$

= 767.23 / 22.2

= 34.56 Ah

Energy = 34.56 x 1,000

Energy = **34,560 mAh**

So, Total Energy require for a battery is **34,560** mAh. In market we couldn't get exact MAH. We have to choose for the nearest value like **32,000**

47.SOFTWARE USED FOR AUTONOMOUS FLIGHTS

47.1 MISSION PLANNER AND GROUND CONTROL STATION

47.1.1. The GCS Flight Data Screen

The screenshot below shows the main “Heads-up Display (HUD)” view of the Mission Planner Ground Station. Once we have connected to a vehicle this screen will display the telemetry sent by ArduPilot.

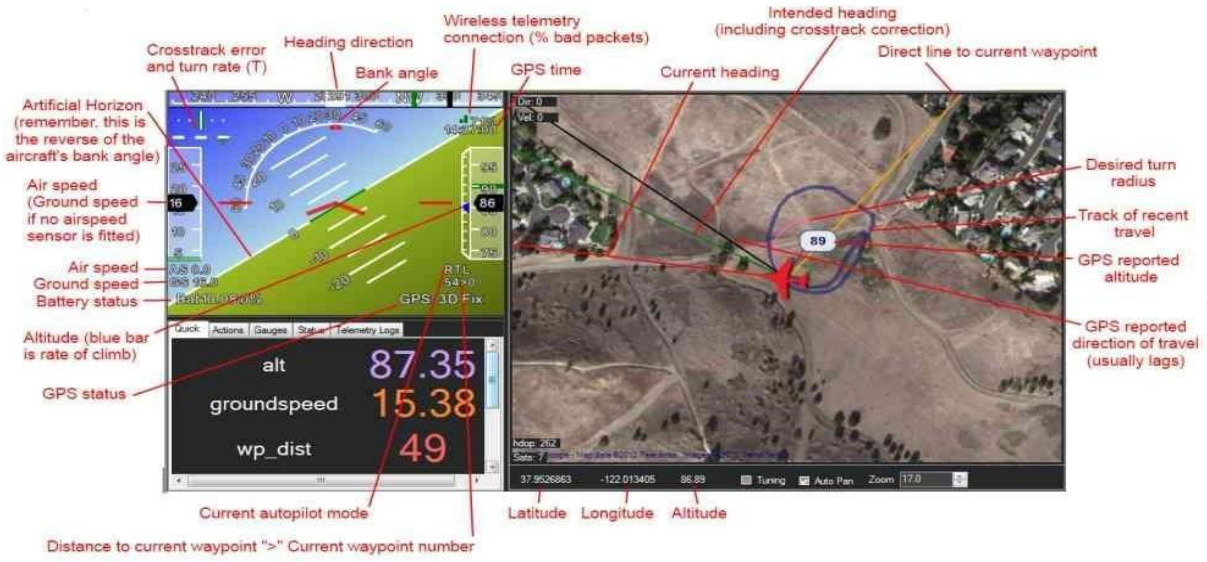


Figure: Misssion Planner Window

A more detailed view of the HUD (with legend) is given below.

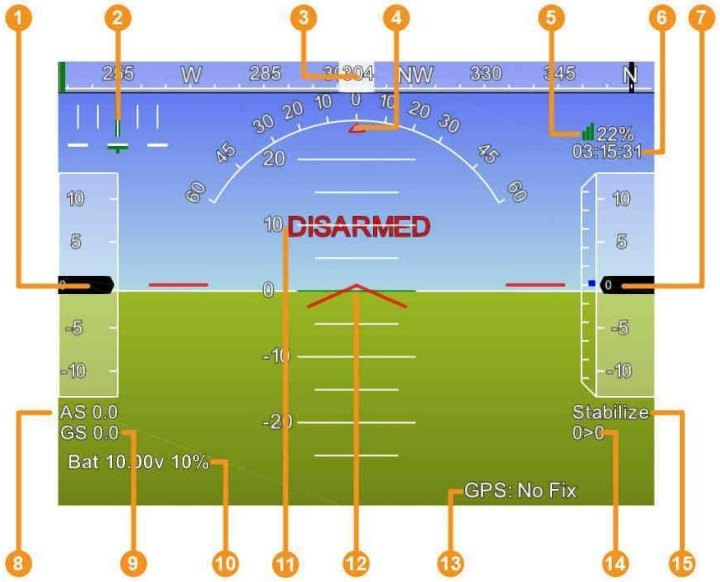


Figure: HUD in Mission Planner

1. Air speed (Ground speed if no airspeed sensor is fitted)

2. Cross track error and turn rate (T)
3. Heading direction
4. Bank angle
5. Wireless telemetry connection (% bad packets)
6. GPS time
7. Altitude (blue bar is rate of climb)
8. Air speed
9. Ground speed
10. Battery status
11. Artificial Horizon
12. Aircraft Attitude
13. GPS Status
14. Current Waypoint Number > Distance to Waypoint
15. Current Flight Mode

3.1.1. Tips for using the Flight Data screen

The map will only show current position when we have GPS lock or are using a flight simulator. Remember how artificial horizon works: when the aircraft tilts to the right, the horizon tilts to the left. (Just tilt our head and we'll see what I mean). This is normal! Please don't tell us it's reversed .For Plane status, the output meaning is as follows:

- **WP Dist:** Distance to next waypoint in meters.

- **Bearing ERR:** How far our UAV is from the perfect line to the next waypoint "Alt ERR": How far our UAV is from the target altitude.
- **WP:** Next waypoint to hit "Mode": Current autopilot mode.
- **Plane output:** The autopilot's outputs on the first four channels.

We can issues mode changes and other action commands in the air with the Mission Planner and other GCSs, but note that we must be under autopilot control for them to take effect. When our RC toggle switch is in the Manual position, we are no longer under autopilot control and no commands will take effect. We must be in one of the other positions (Stabilize, Fly-by-Wire, Auto or any other autopilot-controlled mode) for MAVlink commands to take effect.

We can change the voice used in the speech synthesis in the Ease of Access center in Windows Control Panel. Go to the "Text to Speech" options. If we double-click the HUD it will popout, allowing we to run the HUD full screen on a second screen.

If we double-click on the Speed Guage we can modify the max scale we want to display.

If we enable the Tuning checkbox and double-click tuning we can graph any data that is available in the status tab. This means we can have alt, attitude, or many other options in real time.

We can use custom imagery instead of Google Maps. Press control-F. This allows us to upload our own orthophotos. This requires Globalmapper, as this is currently one of the key steps in exporting in the required format for use in the planner.

47.2. Guided Mode

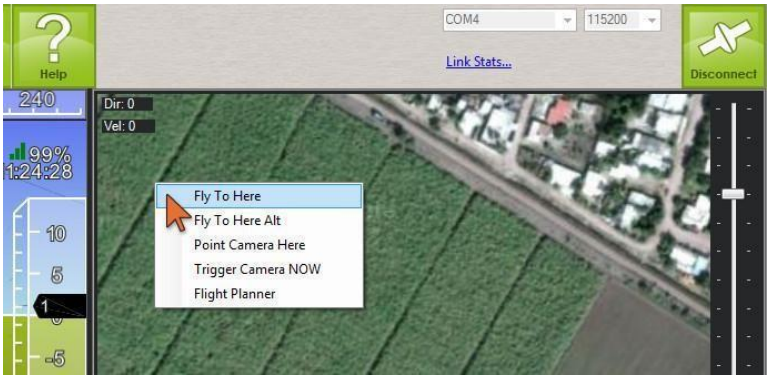


Figure: Setting Guided Mode

One of the most commonly-used features in pro UAVs is point-and-click mission control in real time. Rather than just pre-planned missions or manually flying the UAV, operators can just click on a map and say “go here now”.

That’s now implemented in the Mission Planner. On the GCS map, we can right-click on the map and just select “Fly To Here”. The UAV will fly there and loiter until we give it another command. We call this “Guided Mode”. There are more commands coming in this mode soon, but the functionality is now built-in.

Note: Guided is a separate flight mode. If we enter it, we will remain in it until we do something to change modes. So if we tell it to “go here now”, once it arrives there it will loiter at the Guided waypoint till we tell it to do something else. Something else could either be going to another Guided waypoint (staying in Guided mode) or changing to some other flight mod

48.HOW TO BECOME A BETTER DRONE PILOT (EVEN IF WE ARE ALREADY AN EXPERT)

48.1. How to Become a Better Drone Pilot

Whether we are just starting out or we already have some drone flying experience under our belt, it's important to keep growing our skills. We never know when we'll need to pull off a last minute maneuver to avoid crashing into a tree or safely land a drone in strong winds.

For those using drones commercially, becoming a better drone pilot is essential to career and business growth.

48.2. Keep practicing and challenging yourself

Figure: Keep practicing a drone every day

Ultimately, the best way to become a better drone pilot is to keep flying. This is especially important for beginners who are still very nervous about crashing their drone or running into a building.

Tip: When starting out, buy an inexpensive drone that won't cost us much. Even if it crashes, Again practice in a safe area away from people and buildings. If we have never flown a drone before, I suggest starting with a drone simulator to learn the basic controls and maneuvers.

As we become better and better, keep challenging ourselves with new maneuvers and techniques. Learn how to hover mid air, how to cut throttle when we are about to crash and how to make smooth turns. Flying in different environments will be a challenge for us. An open field will help us to practice our banked turns. A forested area will help us to learn how to weave in and out of tight spaces. Just make sure we are flying in a safe, non-sensitive area.

When we feel that we've mastered the flying bit, start working on our camera work. Good photography requires a combination of a good drone, good flying skills, proper camera control and intuition.

Make full use of all the assists and automatic modes in our drone to take better pictures and videos. For instance, most DJI drones can automatically lock on a moving or stationary object, keeping it in frame as the drone flies in a specific pattern.

48.3. Take Part in Race Events

Figure: Drone race events

If we are more interested in drone racing than photography, we have even more training to do. We need to practice harder and crash many times before we can become a decent drone racer. But for beginners, get an inexpensive racing drone. Most of the times, crash will happen to Propellers, so that is only part need to replace. Most importantly, race with other people on field. It will build our confidence level and skill, even if we lose in the beginning it doesn't matter, it gives us an experience.

48.4. UAV Pilot Training

If we are flying our drone as a hobby, we can do without formal drone training, but still i would recommend it. It would be a big boost to our skill. But if we are planning to get into commercial drone flying, then formal drone training is essential. Not only we learn how to fly safely and do all kinds of maneuvers. We have to pass this test before getting a remote pilot license.

At beginning UAV pilot training is important and ongoing training is essential too especially for commercial drone pilots. It will keep our career growing and ensure we can handle any scenario we encounter out in the field.

48.5. Conclusion

Remember that being a good drone pilot is more than just about flying well and taking stunning pictures. Safety is important. Know all rules regarding operating drones. This will not only keep other people safe, but it also ensures that we don’t get into trouble with the law.

With the increase in the number of dangerous drone-related incidents, the consequences of breaking one of the rules could be severe. It’s also important to have the right drone depending on our needs and field.

49.APPLICATIONS OF DRONES

49.1. Applications of Drone Technology

Drone technology, now inexpensive and accessible, is continuously evolving and being put to several novel uses around the world.

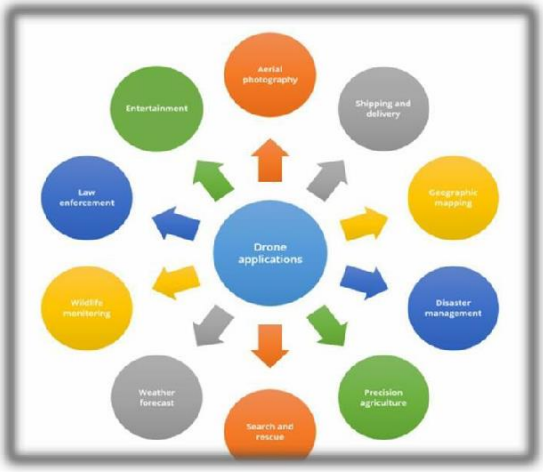


Figure: stunning application in Drone technology

Initially, they were used for military purpose, drones are now being used by individual Entrepreneurs, SMEs, and Large companies to accomplish various other tasks. According to juniper research, by the year 2020, 16 million drones will be sold in the commercial markets of the world and several regulations will be lifted off drone technology. Below are 10 drone applications:

49.1.1. Aerial Photography

Drones are now being used to capture footage that would otherwise require expensive helicopters and cranes. Fast paced action and sci-fi scenes are filmed by aerial drones, thus making cinematography easier. These autonomous flying devices are also used in real estate and sports photography. Furthermore, journalists are considering the use of drones for collecting footage and information in live broadcasts.

49.1.2. Shipping and Delivery

Major companies like Amazon, UPS, and DHL are in favor of drone delivery. Drones could save a lot of manpower and shift unnecessary road traffic to the sky. Besides, they can be used over smaller distances to deliver small packages, food, letters, medicines, beverages and etc.

49.1.3. Geographic Mapping

Available to amateurs and professionals, drones can acquire very high-resolution data and download imagery in difficult to reach locations like coastlines, mountaintops, and islands. They are also used to create 3D maps and contribute to crowd sourced mapping applications.

49.1.4. Disaster Management

Drones provide quick means, after a natural or man-made disaster, to gather information and navigate debris and rubble to look for injured victims. Its high definition cameras, sensors, and radars give rescue teams access to a higher field of view, saving the need to spend resources on manned helicopters. Where larger aerial vehicles would prove perilous or inefficient, drones, thanks to their small size, which are able to provide a close-up view of areas.

49.1.5. Precision Agriculture

Farmers and agriculturists are always looking for cheap and effective methods to regularly monitor their crops. The infrared sensors in drones can be tuned to detect crop health, enabling farmers to react and improve crop conditions locally, with inputs of fertilizer or insecticides. It also improves management and effectuates better yield of the crops. In the next few years, nearly 80% of the agricultural market will comprise of drones.

49.1.6. Search and Rescue

Presence of thermal sensors that gives night vision for drones and makes them a powerful tool for surveillance. Drones are able to discover the location of lost persons and unfortunate victims, especially in harsh conditions or challenging terrains. Besides locating victims, a drone can drop supplies to unreachable locations in war torn or disaster stricken countries. For example, a drone can be utilized to lower a walkie-talkie, GPS locator, medicines, food supplies, clothes, and water to stranded victims before rescue crews can move them to someplace else.

49.1.7. Weather Forecast

Drones are being developed to monitor dangerous and unpredictable weather. Since they are cheap and unmanned, drones can be sent into hurricanes and tornadoes, so that scientists and weather forecasters acquire new insights into their behavior and trajectory. Its specialized sensors can be used to detail weather parameters, collect data, and prevent mishaps.

49.1.8. Wildlife monitoring

Drones have served as a deterrent to poachers. They provide unprecedented protection to animals, like elephants, rhinos, and big cats, a favorite target for poachers. With its thermal cameras and sensors, drones have the ability to operate during the night. This enables them to monitor and research on wildlife without causing any disturbance and provides insight on their patterns, behavior, and habitat.

49.1.9. Law Enforcement

Drones are also used for maintaining the law. They help with the surveillance of large crowds and ensure public safety. They assist in monitoring criminal and illegal activities. In fact, fire investigations, smugglers of migrants, and illegal transportation of drugs via coastlines, are monitored by the border patrol with the help of drones.

49.1.10. Entertainment

Drones are being developed to provide entertainment for players so that they can be used in fight clubs. Known as a cage match, two contenders and their drones are put up against each other. The destruction of any of the player's drones results in the other's win. Moreover, artificial drone intelligence is used in several ways to capture videos and photographs, for example, the Dronie, which is used to take selfies.

As technology advances, drones will become more robust and advanced, accommodating longer flight times and heavier loads. The industry comes with immense opportunities for businesses, gradually becoming inevitable for them. It is, therefore, important for organizations to study the scope of drone technology in their area of business, build the required infrastructure, and test their services across it.

50.DRONE MARKETS AND JOBS

50.1. Market for Drone Operator Jobs Today

The Drone industry is really taking off (pun intended) and drone technology is improving constantly. As a result, Drones are becoming more commonplace in many forms. We can find different types of drones for delivering items, recording videos, and much more. It is no surprise that more companies these days are looking to get different drone pilot or operator jobs filled than ever before.

Figure: DJI Phantom

But what types of drone operator jobs are out there today? The drone industry is opening new doors to many new careers as drone pilots in the air force, real estate, camera operators, unmanned aerial work, aerial photography, precision agriculture, law enforcement, and many, many more. Let's look around to see what we can find in more detail when it comes to appealing drone operator jobs in today's work climate, as well as a few keys on how to make such drones work for we. The jobs that are out there are appealing and unique but it is especially important to watch for how we can find them in many forms.

50.2. Package Delivery Jobs Could Be Big

Some of the most popular drone operator jobs out there are expected to be for delivery purposes. Amazon and Google have been testing the drone delivery process for a while now. This is to determine how well packages can be delivered by such items.

Figure: Delivery using drone

This could be intriguing as we could get a job as a pilot for such a drone. It would entail identifying a location to send an item out to and also with getting a drone loaded up the right way.

This is a special kind of job but the requirements for making it work might be a challenge to handle. The rules for using drones in certain environments, particularly in cities, are constantly being revised

The odds are it might be difficult for some companies to offer these jobs in certain regions. It might be easier to find them in more wide-open spaces or at least in spots where the laws on drone usage aren't as extensive as they could be.

50.3. Movie Shoots are Popular

Drones can also be used for shooting videos for film purposes. In most cases, drones are used for corporate video shoots or for commercial shoots. Some larger film studios may start to work with such drones in the future. Anything that can be used to get detailed videos out there and on display is always welcome.

50.4. Police Support is Open

Drones can also be used for police and surveillance uses. This works in that a drone can be taken out into the sky and used to review items like roads and buildings and other spots from high above. This is often used as a means of identifying criminals or finding threats in larger spaces where many people are in an area.

Figure: DJI inspire

Such drones are designed to be made with cameras that entail more in-depth shots. These include items that use frequencies to see through items. This is a special form of surveillance that can help with finding different items in many spots even if they are relatively well-hidden.

This is an attractive type of job but it would require plenty of training on our end. Also, we would have to go through several background checks to see that we are a suitable person to handle such drones without any complications involved.

50.5. Design Support

Drones can also work with design tasks in mind. These include construction jobs where different spots might have to be reviewed outside a space.

Figure: Solar panel inspection using drone

This is to get a clear idea of how far a construction project is going and what has to be done to complete the work well in time. It is a good point about drones that deserves to be noticed for how effective they can be used.

50.6. Photography Jobs

Photography jobs have often been limited in terms of where they can be held. People often had to go into tight spots to take photos and may be restricted based on the angles at which they can shoot things. Drone photography is expected to be more popular in near future.

Figure: Photography drone

As cameras evolve, it will become easier for a drone to shoot images of all kinds of spots. A drone camera can be used for many projects and can help with spotting many things from high up in the air. It is very easy to get a camera to work well in the sky but it is even more important to watch for how such a drone can be engineered. It would have to be designed with a powerful look that sturdy and effective.

50.7. How Many Jobs?

The number of jobs for drones is expected to increase over the years. Tens of thousands of jobs are expected to be available although it's unclear as to what the total number will be. The drone market is expected to increase by at a third of its original size. This means that there should certainly be great jobs to take a look at.

50.8. Proper Licensing Is Still Required

We would still have to get a proper license for using a drone. Jobs that use drones entail models that are very strong and come with more functions and technical features than what we might be used to elsewhere.

Figure: Flying Inspire

If anything, the world of drone operator jobs is certainly expected to expand in size and become stronger as the years go by. It is impressive to see how such jobs are organized these days as people can use drones for many functions. The market will certainly change over time so be on the lookout if we're interested in a career involving drone usage.

51.MAINTENACE AND OVERHAULING OF DRONES

51.1. PREFLIGHT CHECKLIST

51.1.1. Battery charges

Check that the flight battery, controller battery and our mobile device are charged up and ready to go. If we plan on using our GoPro, make sure its battery is fully charged as well.

51.1.2. Flight equipment

Check for damaged or loose components

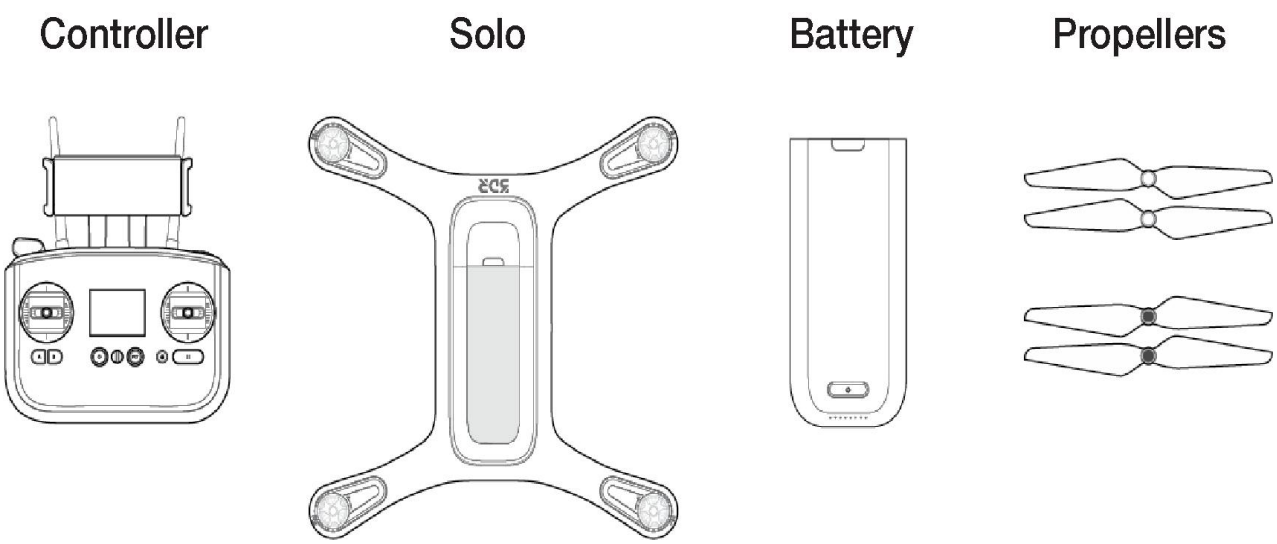


Figure: Flight Equipment

51.1.3. Filming and streaming equipment

If we plan on using our GoPro with Solo, attach our GoPro and establish a live feed through the Solo App to make sure everything is communicating properly. Now is also a good time to make sure our Micro SD card has enough available storage to record our upcoming flight.

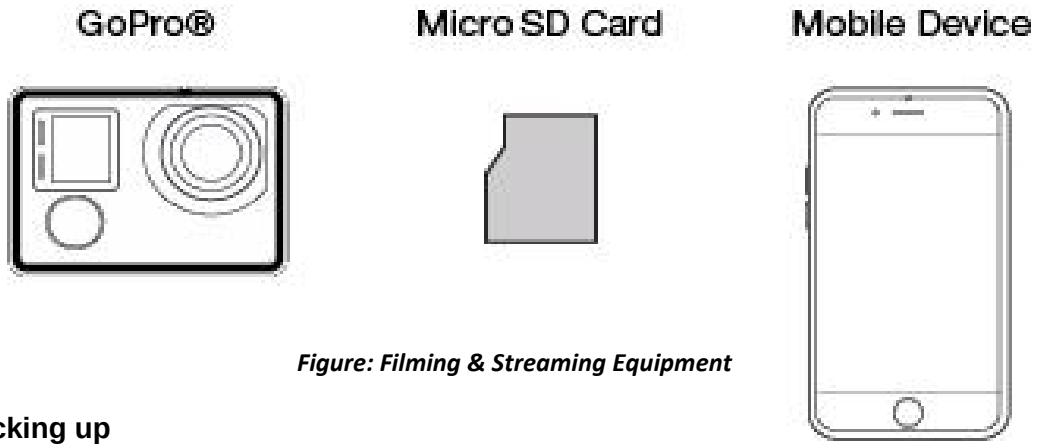


Figure: Filming & Streaming Equipment

51.1.4. Packing up

Now that we have to make sure everything is in good working order, pack all our items

carefully in our Solo carrying case. Make sure each item is snug and secure—it would be a shame to make it to the field to find something has broken during transportation.

51.1.5. Check Our Flying Location For…

51.1.5(i) People:

Whether we are a veteran pilot or new to flying, never fly around people! Unforeseen flight hazards can occur at any time and we are ultimately responsible for the safety of ourself and others.

51.1.5(ii) Inclement Weather:

Solo is not designed for harsh weather conditions. If it is windy, snowing, raining etc. pack up and wait for calmer skies.

51.1.5(iii) Surrounding Airports

Stay at least five miles away from surrounding airports.

51.1.5(iv) Interfering Wi-Fi Networks

Stay clear of crowded Wi-Fi environments. If we are in an area with many different Wi- Fi networks, our connection to Solo will not be as reliable. Also, tall objects such as telephone poles and cell towers cause Wi-Fi interference, so make sure that we are clear of these as well.

51.2. Setting Up To Fly, Final Checks…

51.2.1. Propellers

Check that the propellers are correctly attached and spin smoothly without obstruction when turned. Once again, check the propellers to be sure they are not bent or chipped as damage can occur during travel.

51.2.2. Antenna Configuration

Angle the antennas down and away from the controller so they are approximately perpendicular with Solo in flight. Tilt each.

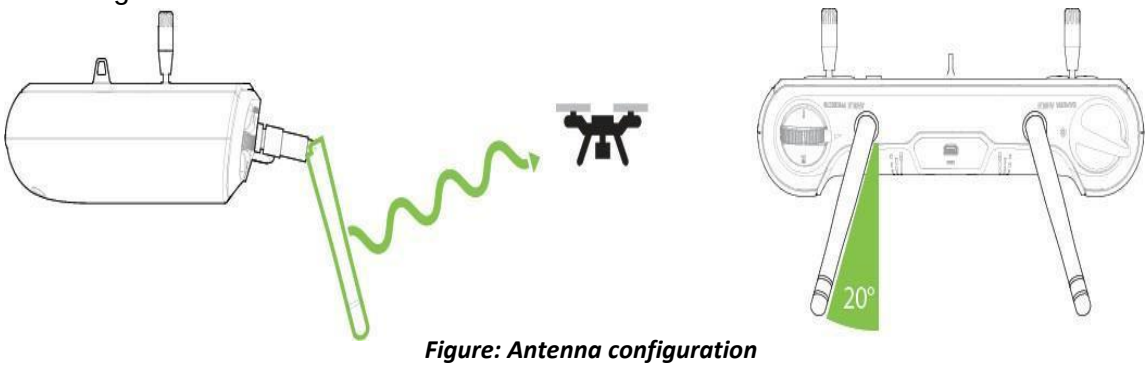


Figure: Antenna configuration

51.2.3. GoPro Configuration (optional) / Camera

Before attaching our Gopro to Solo, make sure to insert our Micro SD card and check that we've applied the recommended Gopro settings. Once we've attached the camera, establish a live feed make sure the Solo App is registering the GoPro feed.

51.2.4. Level Takeoff Surface

For a smooth takeoff, Solo requires a flat and solid launch surface.

51.2.5. Safe Takeoff/Landing Area

Make sure Solo has 20 ft of space in each direction to take off from and land on. Depending on the GPS strength at our location, Solo's Return Home feature might require a little extra room.

51.2.6. Return Home Accuracy

Since GPS strength can vary from location to location, the exact landing point of a Return Home call can differ slightly from the original launch point. Just so we know where exactly where Solo will land in the future, take off with Solo, fly out a small distance, and test the Return Home feature to see where Solo has pinpointed to land.

51.2.7. Give Our Surroundings One Last Check!

A good amount of time has probably gone by since beginning our pre flight checks, leaving time for people to have wandered into our flying area while we were busy making our way down the list. Give our surroundings one more good look for any potential flying hazards and just remember to use common sense for safe flying.

51.3. Flight Environment

How high are we flying? ü Are we flying near an airport, and do we need to let Air Traffic Control know of our flight plan?

Do we have permission from the property owner if we're flying over private land? ü Have we surveyed our surroundings, looking for people, animals, buildings, etc.?

Avoid inclement weather. Fly in winds under 10-15 mph (or 15-25 kph). Avoid precipitation.

51.4. Taking Off Checklist

φ) Position the aircraft nose forward (facing away from we).
κ) Slowly increase our throttle to take off.
λ) Hover at eye level for 10-15 seconds.

μ) Yaw left and right as we listen for any abnormalities—anything that sounds loose, and weird vibrations, etc.
ν) Fly safe! Keep a direct line-of-sight and use a spotter if necessary.
ο) Monitor our battery usage and start returning to our landing zone with 25% battery remaining.

51.5. Post Flight

- Shut down the UAV and disconnect the batteries. Turn of the transmitter, and power down the camera or sensors.
- Check the UAV for signs of damage or wear. Secure the aircraft, and ensure it is out of the way of bystanders.
- Check the pictures and ensure that the UAV recorded what we set out to record. If not, consider redoing the mission.
- Keep logbook entries recording our fight time and what we did.

52. DRONE EMERGENCY PROCEDURES CHECKLIST

ACTION IF DRONE FLIES AWAY	ACTION IF DRONE CATCHES FIRE
MAINTAIN visual contact with aircraft CONTACT ATC via two way radio (as required) VERIFY remote controller is powered on TOGGLE mode switch to middle or lower position **IF UNABLE TO REESTABLISH LINK:** CONTINUE to maintain visual of aircraft UPDATE ATC with the aircraft position (as required)	EXECUTE flight termination procedures ATTEMPT to extinguish the fire **ONCE EXTINGUISHED:** USE non-alcoholic liquid to continue to cool **IF UNABLE TO EXTINGUISH:** CALL 101
ACTION IF LOSS OF GPS *If GPS signal is lost in flight, "Return to home and intelligent flight mode will not be functional"* **IF UA IS FLYING ERRATICALLY BUT STILL LINKED** SWITCH to "A" or "ATTI" mode to disable GPS CONTINUE flight without GPS PILOT the UA to a safe landing area aircraft PERFORM a manual landing and shut down	**ACTION WHEN COMMUNICATION LOSS OCCURS** MAINTAIN visual contact with aircraft VERIFY remote controller is powered on MOVE toward aircraft if possible **IF UNABLE TO REESTABLISH LINK:** CONTINUE to maintain visual of aircraft UPDATE ATC with aircraft position (as required)
ACTION WHEN DRONE BATTERY INDICATES LOW MAINTAIN visual contact with aircraft IMMEDIATELY return aircraft to you for landing **IF DISORIENTED:** USE "Home Lock'' to bring aircraft back for landing **IF STRONG WINDS PREVENT RETURN FLIGHT:** USE camera to locate suitable divert location LAND aircraft	**ACTION IF THERE IS A COLLISION IMMEDIATELY** release all control sticks **IF AIRCRAFT REGAINS STABILITY AND HOOVERS:** MANEUVER aircraft away from object RETURN for a safe landing and aircraft inspection **IF AIRCRAFT DOES NOT REGAIN STABILITY:** INITIATE manual motor shutdown to reduce speed of impact and protect people and property

53.LIST OF DRONES IN ARMED FORCES

NAME	MANUFACTURER	IMAGE
Heron	Israel Aerospace Industries, Israel	
Searcher MK II	Israel Aerospace Industries, Israel	
Harop	Israel Aerospace Industries, Israel	
Harpy	Israel Aerospace Industries, Israel	
Nishant	DRDO, India	
Lakshya	DRDO, India	
Rustom 2	DRDO, India	
Netra	Ideaforge, India	
JR 1	Johnnette Technologies, India	
A4 Asteria	Asteria, India	

54.DO'S AND DON'TS

DO & DON'TS REGARDING OPERATION OF RPAS

Unmanned Aircraft System (UAS)/ Remotely Piloted Aircraft System (RPAS), commonly known as drones/ UAV, is a new addition to the aviation sector. This technology has promising effect on economic growth of India; both manufacturing and service industry.

As more people enter the commercial and recreational hobby drone scene; the prospects for drone accidents/ incidents also multiply. This applies not just to newcomers/ amateurs

But even to professionals.

Here are some operational safety tips to ensure that you have a better and safer flying

Experience, not just for yourself but the people around you.

Do's

- Ensure your Drone (except Nano in uncontrolled airspace upto 50ft) is Digital Sky "No Permission- No Take off" (NPNT) Compliant
- Obtain Unique Identification Number (UIN) from DGCA for operating in controlled airspace and affix it on your drone
- Obtain Unmanned Aircraft Operator Permit (UAOP), if applicable from DGCA for commercial operations and keep it handy
- Obtain Permission before each flight through Digital Sky Platform Ensure drone is in good condition (not damaged) and fit for flying safely.
- Keep an eye on interference: Interference can be from mobile devices or blockage of signals, do watch out when flying your drone.
- Fly only during daylight (after sunrise to before sunset) Fly in good weather: Good weather lets you not only fly your drone better but also keep track of it in the air.
- Fly in visual line of sight (VLOS): Always be within visual range of your drone. Follow Flying Guidelines Do your homework before spending the considerable money for a drone.
- Make sure you clearly understand all operational and regulatory aspects. Be aware of Airspace Restrictions/ No Drone Zones Do stay away from airports and heliports Respect privacy of people
- Keep local police informed about your drone flying activity. If you are ever approached by police provide all requisite information.
- Do log your flights and intimate concerned authorities (like DGCA, local police etc.) of any incidents/ accidents

Don'ts

- Don't fly a Nano drone above 50ft (15m) from the ground level
- Don't fly a Micro drone above 200ft (60m) from the ground level
- Don't fly drones more than 400ft (120m) from the ground level
- Don't fly drone near other aircraft (manned or unmanned) Don't fly drone near airports and heliports

- Don’t fly drone over groups of people, public events, or stadiums full of people without permission
- Don’t fly drone over government facilities/military bases or over/ near any no-drone zones.
- Don’t fly drone over private property unless permission is given.
- Don't fly drone in controlled airspace near airports without filing flight plan or AAI/ADC permission (at least 24 hours before actual operation).
- Don’t drop or carry hazardous material
- Don’t fly drone under the influence of drugs or alcohol
- Don’t fly drone from a moving vehicle, ship or aircraft

55. DRONE PILOT LOG BOOK

YEAR:		DRONE NAME	MASTER PILOT NAME	STUDENT PILOT NAME	EXERCISE/MISSION	DAY HOURS	NIGHT HOURS	REMARKS
MONTH	DATE							
GRAND TOTAL: _____HOURS _____MINUTES					PAGE TOTAL			
					TOTAL CARRIED FORWARD			

ORGNAISATION SEAL:	APPROVING AUTHORITY SIGNATURE:

56.INCIDENT / ACCIDENT REPORT SHEET

Date	Pilot Name	Aircraft Type	Flight Time		Exercise/ Mission	Battery Voltage Before Flight	Description of Incident /Accident Occurred	Battery Voltage After Flight	Part Damaged	Place	Action to be taken

	PILOT'S SIGNATURE	APPROVING AUTHORITY SIGNATURE A

57.TROUBLESHOOT LOG TEMPLATE

Date and Time	Type of Aircraft	Maintenance task	Type of Maintenance	Type of Activity	Duration in hrs/Day	Place	Remarks
MAINTENANCE ENGINEER'S NAME & SIGNATURE			**APPROVING AUTHORITY SIGNATURE AND SEAL**				

58. FLIGHT LOG BOOK SHEET TEMPLATE

The RPAS Flight Log is used by the Remote Pilot to record details of the flight times and the Pre/Post Flight Checks conducted on UAV. When a RPAS Flight Log becomes full, the Remote Pilot will transfer the cumulative total of flight hours to a new RPAS Flight Log and forward the completed RPAS Flight Log to the Maintenance Controller. The Maintenance Controller will file the RPAS Flight Log for each UAV operated under the authority of the UAOP and keep this record for the life of the UAV

FORM 100A								JT – 100A
Aircraft		Pilot Name						
GCS								
Date		Last Flown Date		Takeoff Date & Time				
Payload		I/O Battery Voltage before Take off		Battery Voltage Post Landing				
Aircraft Last Flown		Battery Specifications	Type	MAH	C	Battery Health	Good / Moderate	
Total Clocked hours post servicing		Telemetry Connected	Yes / No	Mission Type				
Aircraft Last Servicing Date		Wind Speed		Sky Condition	Clear / Cloudy			
GPS Health		I accept the aircraft under the above conditions and clarify that, "I have not consumed alcohol in the last 8 hours."						
		Signature						
		Remarks Post Flight						
Remarks		Handover Signature						
		Peak Current Clocked (in Amps)		Hover Current Clocked (in Amps)				
		Aircraft Condition	Healthy / Crashed	Flight Time				
Handover Signature		Remarks						
Name								
Takeover Signature		Takeover Signature		Name				
Name								