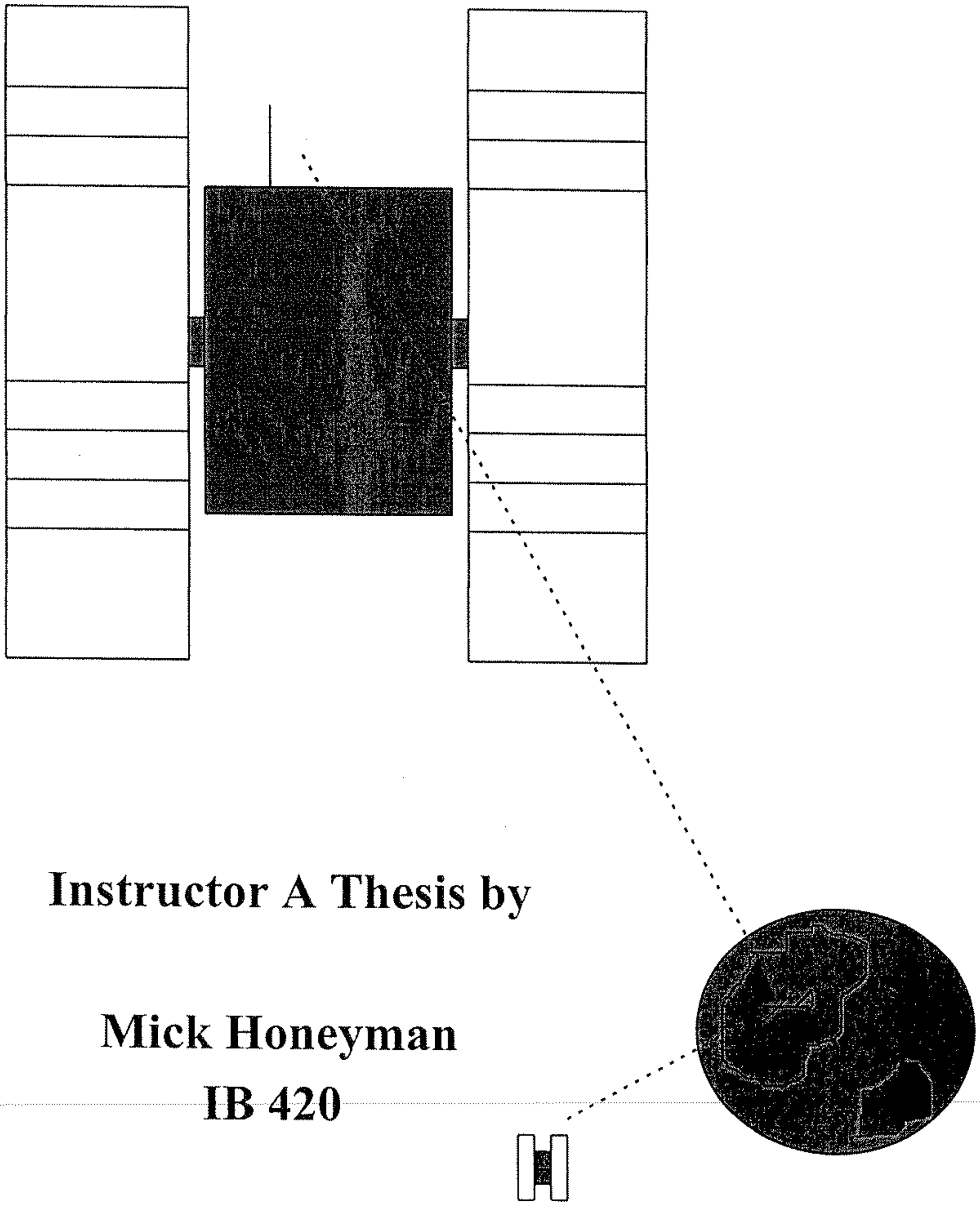
# GPS AND PARACHUTE OPERATIONS




**Instructor A Thesis by**

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**IB 420**

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*Introduction:*

The portable GPS unit is very common these days in parachute aircraft and is one of the latest state of the art navigation aids to hit the market. Every weekend jumpmasters and pilots discuss waypoints and tracks and distance to target, all under the banner of spotting the aircraft correctly to enable us to put jumpers (especially students) safely onto the drop zone.

On a bad day with 100% cloud cover you will hear from impatient skydivers that GPS is the solution. On another day when the batteries are dead you will see concern on the faces of some skydivers who will now have to spot for themselves! Both of these examples give rise to some concern that the benefits of GPS will be abused and we could see the next generation of skydivers lose the ability to spot.

With correct education and adhering to our operation regulations which teaches spotting early in the licence system, this should not be the case and GPS would be the back up aid to spotting as the Cypress is to pulling a reserve handle.

This thesis is written to educate the jumping community, particularly the newer members to our sport, as to what the GPS is and what it does, the advantages and the disadvantages of using GPS in normal parachute operations, as well as some of the more specialist areas of jumping. It will also highlight the extra work and pressure that it places on the more inexperienced jump pilots in the more hectic airspace and the accuracy that we can expect if used correctly.

It is not intended to be a handbook on how to use GPS (there are numerous types on the market and this would be down to those individual jumpers reading the handbook when they can) but more a guide on the limitations of the unit and the person operating it. This should enable skydivers to ask for realistic information from jump pilots and to understand the accuracy of information requested before they leave the aircraft. Hopefully the more experienced jumpers can guide the lesser experienced from bad habits and a more realistic approach to the responsibility of spotting.

This thesis ends with view points from the Chief Instructors and Chief Pilots from many drop zones in Australia. Of all those who replied to the distributed survey we get to find out what these DZ operators and pilots really think of GPS, how the sport should use it and what we should know to introduce this great navigation tool into our sport properly and safely.

*Navigation before GPS*

Before the advent of GPS pilots used various systems of navigation to help them find their way around the skies. These were both local and wide area systems which are still in use today.

We have come a long way from when pilots had to navigate by "dead reckoning" or "track crawling" which was achieved by constantly looking outside of the aircraft for visual clues. Bad conditions, ie cloud and poor visibility, hampered this type of navigation. Parachute flying during this time depended heavily on good weather, good local knowledge of both the drop zone and local weather conditions by the pilot and jumpmasters.

Over the past few years navigational aids such as VHF Omni Range (VOR) for bearing, Distance Measuring Equipment (DME) for range and Non Directional Beacons (NDB) have all shown themselves to be useful local area navigational systems.

Most of the airfields around the USA and Australia have some type of this local navigation system and these have a reliability of virtually 100%. However close to the earth's terrain this can give some unreliable coverage and it is only when you get to a higher altitude that you start to gain a better coverage benefit.

Most VOR stations are line of site and are designed to overlap each other to minimise coverage problems when equipment becomes faulty. It is these same older systems that are becoming useful additional aids for navigation whilst using GPS.

However, it was the total area coverage solution that failed the system and it soon became apparent that to have one system with world wide coverage was indeed the ideal way to go.

The first of these systems was the land based Long Range (LORAN) navigation system which was developed for the US Military, but this was only a half measure. This wide area system covered a huge percentile of the US and parts of Canada, plus areas that had significant military importance to the US. The latest version LORAN-C , run by the US coastguard, is still in use today but has been proven to be inadequate for modern survey accuracy. The standard accuracy is around 400m.

The idea of GPS has been updated and developed since its early concept in the seventies and we now seem to have the answer to the much needed wide area system of navigation.

### *Background To GPS:*

The **NAV**igation **S**atellite **T**iming **A**nd **R**anging (NAVSTAR) Global Positioning System (GPS) is a satellite based system that is regarded throughout the world as an accurate tool for land and air navigation[1].

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[1] There is also a Russian equivalent of GPS called GLONASS which is well into development but has not yet achieved as much as GPS has in production, reputation or indeed market exposure.

It currently utilises a system of 24 satellites (including three spares) and can work continuously and accurately, world-wide, in any weather condition. It was officially stated as having Full Operational Capability (FOC) in April 1995.

GPS is sponsored by the United States Department of Defense (DOD) which guarantees civilian access through an agreement with the US DOD and the US Department of Transportation (DOT). In Australia AUSLIG is the Federal agency responsible for GPS. It is they who monitor its progress for operations inside Australia.

With this guarantee for civilian access, GPS is now available for a wide range of uses, to various groups of users. These include such applications as:

1. Military.
2. Recreational.
3. Emergency search and rescue.
4. Exploration.
5. Surveying and mapping.
6. Scientific research.
7. Space applications.

Not only is it an extremely accurate navigation system which can be of benefit to all of the above but also an affordable solution to the General Aviation market including parachute operations.

The GPS unit can provide accurate 3D navigation information, giving position, velocity (speed) and time. In parachute operations our known position and velocity at different heights are important items of information to assist us with spotting. The GPS system is receive only, the GPS unit receives the information directly from the satellites. The GPS unit does not need to access the system at all (unlike a mobile telephone) therefore there are no busy signals to contend with, just constant "on tap" navigation information.

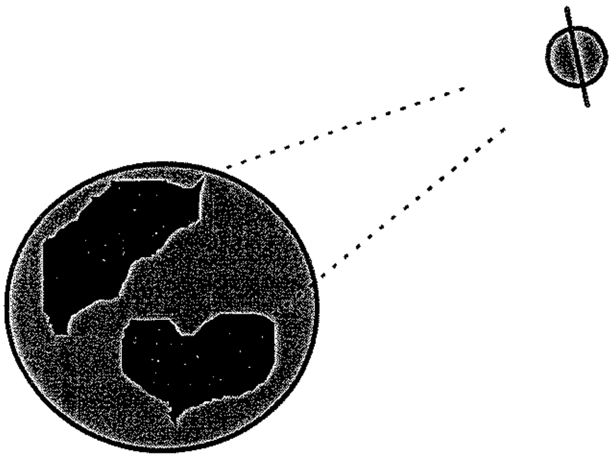
The GPS system works using complicated radio and satellite communication techniques and as it's satellite based, the signals to and from the satellites have to overcome numerous obstacles that can cause error's in the system.

These includes ionosphere group delay, propagation delays, clock errors, doppler shift compensation and multi-path propagation. These barriers to the system are efficiently dealt with by highly technical error correction methods. It is only when it comes into contact with the human being that any major positioning errors can start to creep in.

*System Operation*

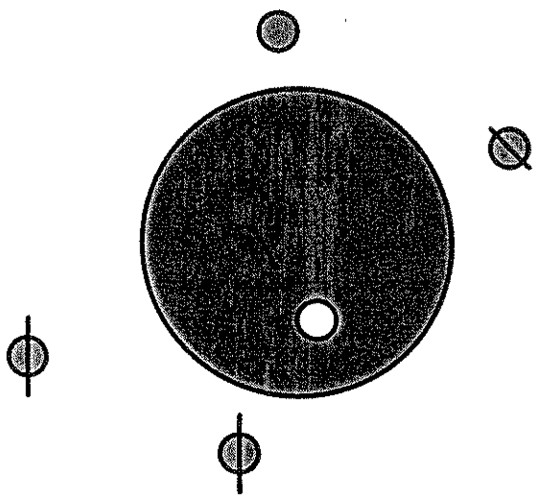
Most satellites in normal communications are in geo-stationary orbit at a distance of 33,000 km from the earths surface, this means that at this orbit they move at the same speed as the earth rotates. This gives the impression that a satellite is always in the same position above the earth at any one time. Fixed installations therefore do not need any expensive tracking systems.

Basic communication satellites act like very high, and very expensive radio repeaters!

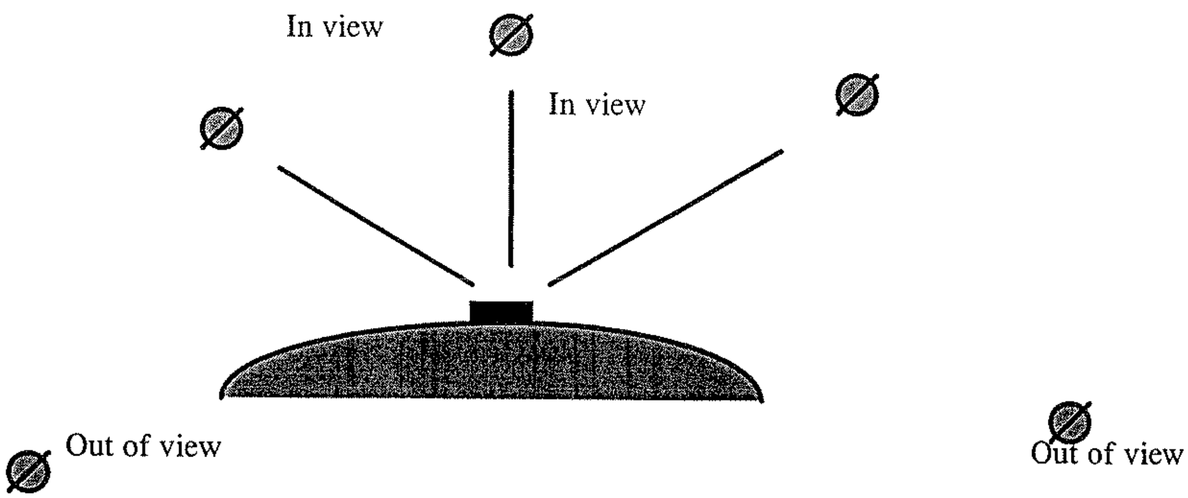


Using this method a satellite can be used to bounce a signal from the bottom of the globe to the other side of the world. This is particularly effective when there is no line of site between the two links in the system.

Satellites in the GPS system are slightly different. They circumvent the earth at a lower orbit, 20,200 kms, in six orbital planes, with four satellites in each plane.



Each GPS satellite will orbit the earth approximately every 12 hours. They are positioned in such a manner that there are at least six in view[2] at any one time. At least four satellites are required to obtain a good accurate 3D position ( lat, long and altitude).




Your unit's location in relation to the position of these four satellites is then used to determine your actual position over the earth.

System control and maintenance is achieved by satellite ground stations maintained and controlled by the US DOD making them responsible for the accuracy and availability of the entire GPS system.

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[2] 'In view' means above the surface of the earth where your unit can communicate with it.

The master control station is established at Falcon Air Force Base in Colorado Springs. The monitor stations are in Hawaii, Kwajalein, Diego Garcia and Ascension Island. In Australia AUSLIG maintains 8 permanent tracking stations plus separate sites in the Cocos Islands, Norfolk Islands, NZ and Antartica.

Users of the system use GPS receivers that are specifically designed to receive, decode and process the low level GPS satellite codes and data messages. These are passive units and range from small personal units for backpackers and bush walkers up to sophisticated units for airlines and the military.

## GPS Coding and Types of Service

There are two types of coding used on the system which essentially separates the civilian users from the military users. These two codes are the C/A code (Clear acquisition) and the P code (Precise). Civilian users, including our own general aviation category, are users of the C/A code. This is mainly of no great interest to most users but the type of code you use defines the accuracy of the unit.

The standard of accuracy is selected by the US DOD and is not guaranteed to stay the same for life. By using what is known as SA (Selective Availability) they can introduce errors into the system and limit the accuracy of the entire system at any given time. This was meant to limit the chance of anyone using GPS to mount a hostile attack on the American mainland. SA will hopefully be scrapped within the decade once the US military has found ways to overcome the perceived threat.

Therefore at any time the DOD feels there is a threat to mainland USA, Selective Availability can be increased and in an extreme case the GPS system can be made useless. If the accuracy of the system suddenly becomes accurate to within + or - 1,000 m, then we need to know about it before we use it for spotting purposes!

The two main services that the GPS system can deliver are:

a. Standard Positioning Service

b. Precise Positioning Service.

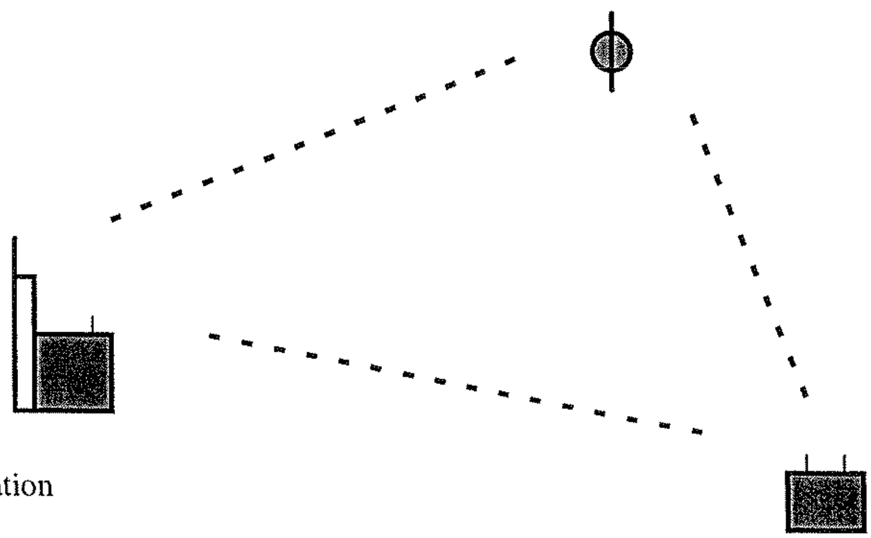
The standard service was originally specified to give you an accuracy of 100m horizontal and 146m vertically (with Selective Availability introduced) 95% of the time. Accuracy for the other 5% could be as much as 300m horizontal!

Whereas the precise service was specified at an accuracy of 18m horizontally and 27m vertically 95% of the time.

The precise service, the most accurate of the two, is dependant on the P code which is protected and therefore not available to the public. This means that the standard service is our limitation for parachute use. However with ever changing techniques some industrial companies, especially in the excavation and mining businesses are utilising GPS accuracy down to 5m with block shift and differential GPS techniques. The latest method RTK (Real Time Kinematic) is extremely expensive but gives an accuracy of 1 - 3 centimetres[3].

*Differential GPS*

This technique requires extra communication equipment (eg two way communication base station, mast, antenna etc) which is located in a position of significant local interest to warrant the extra accuracy, ie one of military significance. By monitoring the satellite data on a fixed known position and comparing it to the signal received from the GPS satellite at the remote user end, the error between the two can be calculated and then passed on to GPS users.



Differential Station

remote station

[3] GLONASS, the Russian equivalent gives approximately the same accuracy as GPS, however it has no Selective Availability errors. But, since its standard accuracy is not as good as GPS it ends up with similar accuracy to the user. Some of the more advanced GPS products, ie some Magellan portable units, have a unit that can track and monitor both systems satellites.

Differential GPS is also seen as a way round selective availability errors but is only accurate if the fixed facility uses exactly the same satellites as the GPS receiver of the user. To be completely accurate the remote station needs to be close to the master station and the speed of the error correction also needs to be high.

At approximately $20,000 for a relatively cheap differential GPS system this type of GPS is unfortunately not economically viable for parachute drop zones, but show the further accuracy available within GPS technology.

*Single Channel or Multi Channel*

Most of the early receive units were single channel units, but now we are seeing more and more multi channel GPS receivers. A single channel is required to monitor and decode a single satellite signal, therefore there can be some confusion when you remember that for an accurate signal the GPS requires at least four satellites in view to give you an ideal 3D positional fix.

A single channel GPS receiver will monitor as many satellite signals as it requires and multiplex (combine) them very quickly to give the user the information they require. A multi channel receiver will monitor multiple satellites at the same time.

To the user there seems very little difference in what they actually see happening on the GPS, but there are a few differences to remember.

Single channel systems are slower and can have some problems when satellites in a lower orbit are being used for positioning information. Also the initial lock in time, the time it takes to lock into a satellite when the GPS is switched on and starts to gain information from it, is longer.

A single channel receiver will have a typical lock in time of 60-90 seconds, whereas a multi channel GPS will lock in within 20-30 seconds. The GPS will remain locked in throughout the time it is switched on, but you can lose lock in high dynamic situations, ie an extremely tight turn on run in.

If this does happen on run in then you may find that you have no GPS information at the most critical time of the flight, ie the exit. Even more of a problem if your skydivers in the back don't like putting their head's out of the door and haven't a clue where the spot is! In this situation a Multi channel GPS would be ideal as they are less likely to lose lock in this situation and also regain lock quicker if they do.

Some manufacturers are making 12 channel GPS receivers which sounds great in theory but unlikely to be used to its full extent in practise.

The downside to multi channel receivers is possible high power consumption which leads to less battery life and higher costs. If this type is to be used on your drop zone then you can eliminate this problem if they are run off a power feed in the aircraft.

*GPS Initial Set Up*

The GPS unit uses an on board RAM (Random Access Memory) to keep stored information in the unit for constant use. This is powered by a small cell to ensure that the information stays in the unit when the GPS is being stored or not in use. This will keep all your local drop zone waypoints ready for immediate use each weekend.

The pilot would usually be responsible for setting up the initial vital information that will be used during the jump operations at the drop zone. This will include waypoints and tracks and also reference points in the vicinity of the airfield. All this information will then be available every time the unit is switched on. If the battery runs flat the information will have to be stored again.

There are some problems with different kinds of GPS batteries, particularly the battery that maintains the internal memory. The chargeable type have an extremely sharp drop off voltage. This leads to the problem of the unit shutting itself off before it can warn the user of low voltage. This will lose all memory stored, ie waypoints and tracks.

The Alkaline batteries however will actually turn off the unit leaving just enough memory to keep the battery charged to preserve the memory and waypoints. This would be the best type of battery to use for drop zone operations, limiting the chances of losing all drop zone information.

When this information is stored at the installation phase all reference points and waypoints entered will correspond to satellite positions at that time, this alone gives rise to a few basic set up problems. Signals from GPS satellites are extremely low in power, having travelled many thousands of miles to get to earth.

Some of these GPS signals are typically 160 dB[4] down on the original signal. The signals are so weak (lower in level than the background noise) that the only way they can be picked up by the antenna is by recognising the discreet code of the GPS signal.

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[4] dBs are a ratio, but to give you an idea just 30dB loss is a signal strength of 1000 times less than the original signal.

Therefore poorly installed GPS antennas in the jump aircraft, or jump aircraft parked very close to buildings or in metal hangers can find it difficult to pick up the signals and store important data on start up. By simply moving the aircraft out to the runway, you will find it easier to lock into the system to obtain the information you need. Also GPS signals are spread spectrum modulated and cannot easily penetrate conductive or opaque surfaces. So when you install the GPS into your aircraft make sure you remember that antenna needs to be **ideally** situated outside the aircraft[5] where it also has clear access to the sky..

Antennas are normally one of the most fragile pieces of the installation and need to be checked on a regular basis for serviceability. A regular overhaul of your GPS installation is highly recommended if you want it to work properly over many years. If your installation is never overhauled or checked and your antenna is inside and poorly sited, then you are introducing losses into your GPS installation.

*GPS During Parachute Operations*

GPS is ideal and legal for parachute operations but with the high accuracy and high regard it has there could easily be a tendency to rely too much on the system for spotting purposes. With a good pilot it is far too easy to sit back and rely on the pilot for the spot.

There is also a concern that GPS could be seen as a way around the problem of jumping through total cloud cover. Both of the above points if abused are a catastrophe waiting to happen.

The operational regulations put responsibility on the person who spots the aircraft.
Their main duty is to ensure that they can see the ground and the target below and ensure that the jumpers who will leave the aircraft have a clear column of air to fall through. Until they manufacture a GPS unit that has eyes and actually checks this for us, the responsibility is still ours.

Before parachute operations start for the day the forecast winds should be obtained by the rostered pilot. This will give you the winds, as they are expected to be, from 2000 ft AGL up to 12000 ft AGL. To obtain the winds from 2000ft AGL down to ground level, a drifter will give you these as they actually are.

Once an idea of the correct exit point has been calculated there is nothing wrong with a pilot and spotter using the GPS to confirm the expected winds. This leaves the jumper who actually spots the aircraft with the confidence that they are in the right place.

[5] For GPS that are used in an IFR situation special installation procedures are in place and enforced by CASA (CAAP 35-1).

Some drop zones can use GPS so efficiently that they use it from the first load of the day, while at the other end of the scale some drop zones rely on the trial and error method.

It is a great idea for all jumpers and instructors to have a good working knowledge of the GPS as well as the pilot. This will give him/her an understanding of what the limitations are and the availability and accuracy of the information the GPS can give.

For a pilot in a busy airspace environment where they are constantly making calls on the various frequencies. There is not much time to constantly monitor a GPS unit, especially if the pilot is inexperienced.

Two of the main pieces of information that a parachutist will often require are:

*a.* *Actual wind direction.*

*b.* *Actual wind speed,*

To achieve this **100% accurately** using only the GPS, the jump pilot will need to fly at a constant altitude for a set time and run a calculation. This can take approximately 2-3 minutes depending on the ability of the pilot in using the GPS unit. This will then enable the pilot to give a **completely** accurate wind speed and direction at that height. He will then need to do the same at the other heights that wind speed is needed. This is obviously not an attractive proposition to an aircraft operator who has economy in mind. It is also time consuming and adds to the pilot's workload.

However the GPS can still give extremely good accuracy within the climb but for a typical aircraft sortie at a typical DZ where the aircraft is constantly climbing to altitude, the error margin for accurate wind speeds at height using purely the GPS start to widen, especially with an inexperienced user.

To compare the two extremes, from an experienced user we get accurate information along the lines of 12 knots from 160 degrees while from the inexperienced user we end up with "......erm not too much wind .......roughly South ....ish!".

However when the initial spot has been calculated by the forecast winds, trial and error or just good luck, the GPS is then a great tool for actually flying to the right point in the sky for the jumpers to exit.

*GPS Navigation Basics*

Already we have mentioned waypoints, tracks and using reference points in relation to the pilot working out an accurate position above the ground.

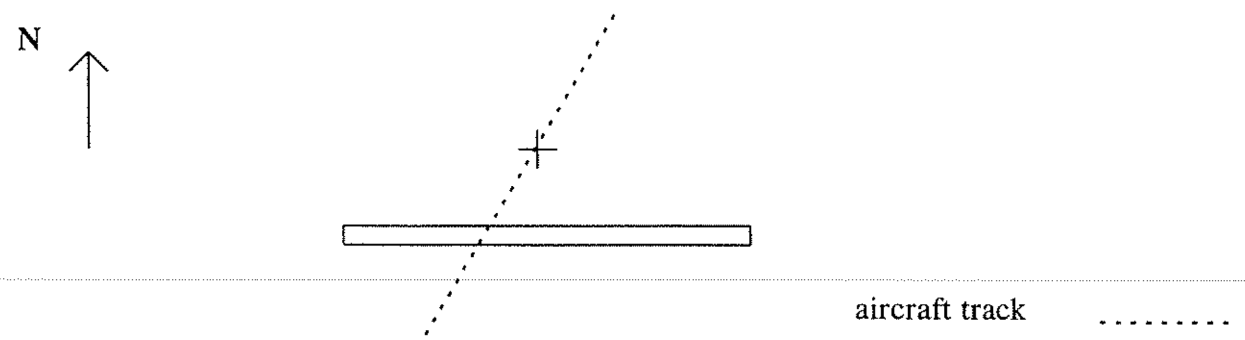
These are the basics to GPS navigation and along with some very useful functions that the GPS provides make the GPS the navigation aid that it is. These are explained briefly below.

**Tracks**

A track is the direction that the aircraft flies over the ground (ie over the top of the airfield). Some GPS receivers use a moving map display while others just incorporate an alphanumeric display. A track on an alphanumeric display is shown below. In the example GS is Ground speed, RNG is range and WPT is waypoint.

| | | | |
|---|---|---|---|
| - - - - - - - - - - - - - - | | > GS | 20 Kn |
| > TRACK | 204 | > RNG | - - - |
| NO ACTV WPT | | > ETA | - - - |

The above example, and the diagram below shows the aircraft flying in a line, over the top of the drop zone , at a bearing of 204 degrees and at a ground speed of 20 Knots ie:



**Waypoints:**

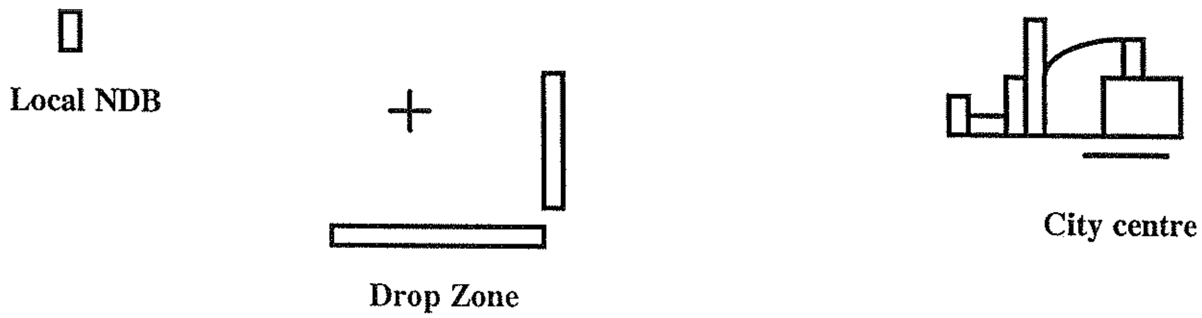
Waypoints are fixed positions that have been programmed into the GPS receiver to help the pilot to navigate the aircraft. These can be pre-programmed before the journey or programmed in the air "over the top" as you fly.

These in our situation can basically be the exit point, the place in the sky above the drop zone that the jumpers need to leave the aircraft. By using tracks and the aircrafts relation to local VORs or other reference points programmed as different waypoints, this can be achieved very easily with a great amount of confidence.

Reference points can be stored as waypoints to make finding your position easier. Aviation reference points differ slightly from normal navigation reference points for obvious reasons. A nearby airport would serve as a good waypoint for many reasons. Most airports will have VOR's or NDBs on site.

If a VOR or an NDB is nearby then this signal can be used as a further reference point for where the drop zone is and also as a reference point to keep clear of, especially if the airport is busy.

An ideal situation for a jump pilot is to have a couple of reference points stored so that he can be confident that he is over the top of the right place, ie the drop zone.




**Functions**

There are some very good functions with most GPS units that make flying and navigating the aircraft very easy. We have already mentioned tracks and waypoints which are the basics to the exercise.

A function called **NAVSUM** will show you basic information between waypoints:

| | |
|---|---|
| **AD-DZ** | **> GS 104** |
| **> TRACK 210** | **> RNG 1.2** |
| | **> ETA 1.2** |

As you can see this gives you all the information you require to fly to the point you want, ie exit point. In the above example the aircraft is flying towards the DZ waypoint from the Adelaide waypoint (Shown as AD-DZ) at a ground speed of 104 Knots, the range (distance ) shows he is 1.2 nautical miles away from the destination waypoint DZ and his estimated time of arrival, the ETA, shows he is 1.2 minutes away from the destination waypoint.

The screen will continuously update as you get closer, this is how the pilot can pass information back to the jumpers, ie "one mile" or "30 seconds". Most pilots will set themselves up early and just monitor the screen, this then gives them time to fly the aircraft ready for the exit, ie trim the aircraft and reduce the speed.

Using this technique of waypoint to waypoint is a great idea for added security over the drop zone. If one of your waypoints is the cross and the other the exit point then this should help stop any mix ups with waypoints and the chance of someone getting out at the wrong place.

Another similar function is the **GOTO** function. This is basically a way for you to steer towards exit point from anywhere in the sky, ie GOTO the DZ waypoint. From there it then works very similar to the NAVSUM function.

**WINDS ALOFT** is also a very handy screen, this can take some time to run the calculation but gives valuable information for checking forecast winds:

| | | | |
|---|---|---|---|
| **HEADING:** | **220** | **TAS:** | **89 Kn** |
| **WIND FR:** | **283** | **AT:** | **25 Kn** |
| **THE HEAD WIND IS** | | **10.0 Kn** | |

The above example shows that the aircraft is flying at a heading of 220 degrees with a true Air Speed (TAS) of 89 Knots (entered by the pilot), the wind is coming from 283 degrees at 25 Knots. This type of calculation is available to jumpmasters via the pilot, but requires a short duration of time to run the calculation. A possible error here is the wrong true air speed put into the GPS.

Finally "Course to Steer " is another common function. When used the GPS unit will notify the pilot, **if he is watching**, if he wanders off the given track towards his intended position, ie exit point. This is done by the GPS showing the change in track and also giving a direction and the change in bearing required to get back onto the desired track.

We must remember that a track is our direction of flight and our accuracy of run in depends on how accurate the aircraft keeps on that track. This function is ideal for keeping the user accurate and running in where we want to be.

In summary the basics of GPS navigation are very easy to follow, the user can make things very easy for themselves by using exclusive waypoints and should, very quickly, gain a great deal of confidence in the equipment.

*CI SURVEY RESPONSE:*

Two surveys were compiled and sent out to all parachute centres asking Chief Instructors and Chief Pilots their views on the GPS in general and their concerns and future thoughts.

A copy of both these surveys are attached to the end of this thesis as reference material.

The answers to this survey highlight some very interesting and diverse thoughts as to how GPS is being used and how we can benefit from it further. There were some major concerns highlighted that the up and coming skydivers could lose the art of spotting, and that commercial centres would use it as an aid to jump illegally with dollar signs in mind.

The first survey will look at the Chief Instructor's comments, this survey was very well received with over 64% of the 48 surveys returned. Almost everyone replied quickly and gave realistic views and comments. This survey and line of questioning was designed to see what the thoughts were at the top end of the instructional ladder.

*GPS in use in Australian:*

Of all the drop zones that responded to the questionnaire, 82% use GPS. Of all CI's who responded to the survey only six drop zones did not use it. The Skydiving magazine also mentions GPS trials in USA (April edition 1997, page 15) which to shows that it is a world-wide parachuting instrument.

The obvious worth of GPS is now coming into contact with an extremely high percentage of Australian skydivers and jump pilots, yet one of the disadvantage's is that there is no training publication in place for either. All advice on GPS seems to be coming from the odd manufacturers handbook or fellow skydivers, some who hold high standings and/or ratings within their club and who basically set the tone and level of education to the up and coming jumpers in our sport.

Qualifications for qualifications sake benefits no one, but if we are to be serious about implementing GPS properly then we will need to incorporate GPS training into parts of the licence table and also in the jump pilot manual?

Just as spotting is currently being taught at AFF level it would not take much to introduce the newcomer to basic GPS at around the same time (If on a GPS drop zone). This can be updated and introduced into training operating manuals and also taken into further consideration when instructor courses are being organised.

One drop zone actually produces its own handout to jumpers at C licence level. This also gives them background information on the local environment. They are then instructed on how to use the GPS themselves and guide the pilot to the correct exit point. This was the **only** survey response that was pro-active in training their jumpers early.

The APF will eventually need to educate the jumping community via seminar, written article (Skyline, Newsletter) or via ASOs etc within individual states, as to what is expected with GPS spotting. A clear understanding of the limitations and disadvantages of the system needs to be taught to all levels of skydiver.

### *Jumpers Reliance on GPS*

The survey showed that 40% of jumpers on drop zones relied on the GPS most of the time when spotting, with 24% using it some of the time. Whereas 35% of replies said that GPS was being used in only certain conditions and when there was complete blue skies everyone then reverted back to visual spotting.

We will cover jumping through complete cloud cover in another section but some of the responses implied that GPS was only used when visual spotting was no longer possible.

### *GPS Versus Visual Spotting*

The answers here were that 80% of those surveyed believed that GPS was the way to the future as far as the main method of spotting was concerned. Very little doubt was expressed as to the outcome but little input was given on how it should be achieved. Most Chief Instructors saw the pitfalls for the unwary, inexperienced or just plain stupid, who showed blind faith in lemming like exits from aircraft using purely GPS.

Some comments include:

1. GPS cannot see other aircraft.
2. Newer jumpers on the DZ rely on the GPS totally.
3. Spotting skills are being lost.

The word that describes everyones thoughts was AID! Use GPS as an aid but also use your eyes and common sense. It is definitely not a "bullet proof vest"!

One response actually mentions the fact that we have a high percentage of jumpers who just cannot spot (we have all seen the jumpers on the drop zone who will do almost anything to get out of spotting) yet we have in our operational regulations the fact that we must be able to spot to gain an A licence! This respondent stated that we should either strike this from the regulations or enforce it.

Further views stated that safety in the air and landing in the right place are the main issues here, making sure that exiting skydivers do not free fall through overflying aircraft or descending AFF students do not land in oceans or built up areas (where some drop zones are located nearby).

The chances of students hurting themselves on landing start to increase dramatically when they land off and cannot use the experience of the TA on landing. One reply mentioned neighbours who do not appreciate off drop zone landings on their property, some are even prepared to prosecute!

Another view mentions being wary of implementing full GPS procedures, particularly around the question of what happens if the GPS breaks down? They are only machines and it will possibly happen, even if its only the batteries going flat. Does the entire load come back down? Does the drop zone stop operating until it's fixed? This respondent also mentioned that now it's not such a big problem but further down the track when we are used to GPS spots and bar talk revolves around "when we use to spot by looking out the aircraft" it possibly could be?

All newer members of our sport should know how to visually spot the aircraft, but does every APF organisation make it easy to achieve experience in spotting?. Some drop zones put a lot of emphasis on introducing spotting to the AFF student and then carrying it on in the B Rel table, but to do so, we need experienced instructors who can spot and a drop zone environment that helps the newer skydivers to carry on with what they learned at an early stage.

There are numerous skydivers who have the required jump numbers for their next licence but are missing the self spotted accuracy jumps. Sometimes this is down to a drop zone culture that tends to put the solo jumpers out last where they have no chance to spot, or it could also be just down to laziness or fear of ridicule.

Now is the time to look at the way we wish to go and start to put some procedures in place before an accident puts CASA in the frame and they enforce procedures of their own.

*GPS Trials in Australia.*

One of the questions in the survey was designed to see if any operators knew of any trials currently going ahead in Australia and if operators wished to see a trial in place. There were 66% who wanted to see a complete trial while only 23% said no.

Comments include:

1. Past trials have been of insufficient standard.
2. Must be conducted across at least six drop zones.

Both Togoolawah and Picton have been using GPS for some months and have indicated that they found it invaluable. These "trials" are however not official and are not sanctioned by CASA. Other responses made mention of many other unofficial trials going on every weekend at various drop zones around the country. Picton and Togoolawah however are very high density parachute operations and would use GPS in a slightly different situation than most drop zones.

Much of the feedback from the two drop zones shows that things have been going very well. The fact that 16,000 descents have been safely achieved in a controlled airspace environment has shown its value to one of the operators.

23% of the survey responses actually pushed for a full CASA approved trial that had defined goals and was run in a controlled way, laying down parameters before the trial commences. One reply stated that trials in the past had been of an unsuitable standard and if we wished to be taken seriously then we had to involve CASA as soon as possible. Not everyone wished to involve CASA but the only way ahead to legally conduct trials was to take this step and gain their support.

Comments include:

1. Everyones using them now, maybe its time for a show trial with CASA?
2. It will prove nothing without CASA approval or support.
3. As long as it's done properly.

Realistic trials may be the answer involving a cross section of drop zones, catering for different operations, different airspace requirements and different aircraft. GPS has been considered ideal for efficient large aircraft operations, making operations more economical is a common comment but it must be done in a safe environment.

*GPS and jumping through 100% cloud cover.*

This question provoked a lot of discussion, 10% of replies said a total unqualified yes, whereas only 17% said no. Over 65% said yes but with a lot of thought and certain criteria that must be met.

Comments include:

1. Only after well documented trials.
2. Only in certain conditions.
3. As long as ground based TCO can verify traffic and only in certain cloud conditions.
4. When cloud base is above planned opening height.
5. Who's going to change the Op Regs first?

If this were to happen there would have to be a restructuring of the APF Operational regulations if GPS were to be used as a means of jumping through 100% cloud cover. In the past year all ASOs and the Director Safety got together on a conference call to discuss ways that APF members could exit safely in various conditions.

More recently the APF indicated in Skyline (February issue 1998, page 9) that a proposed trial was in the initial stages with CASA, all this is a positive step towards jumping in minimal conditions. GPS will feature prominently in the trial.

New Zealand have a clearance to jump through cloud cover via Part 105.25 of their aviation regulations, this is quite simply allowed if they have an air traffic clearance. Whereas in the USA they have to be clear of cloud during the whole descent with clearances of 500' below cloud, 1,000 ft above cloud and 2,000 ft horizontally.

Now New Zealand does not have the air traffic density that the USA have, so we are talking about very different situations. However in Australia, as in most parts of the world it cannot be achieved legally at present.

Our own Operational Regulation number 5.2.4.2 has recently been amended to " **A parachute descent shall not be made unless the parachutists have positively fixed his/her position in relation to the target**" which indicates that GPS (or similar) can be used as an approved spotting aid, other current spotting procedures are:

The jumper who spots the aircraft must ensure that there is a clear column of air to fall through when jumpers leave the aircraft. If we have 100% cloud cover then this cannot be achieved, how is the same jumper going to check that there are no aircraft below or if the cross is still out?

Currently parachuting operations are conducted under the VFR banner (Visual Flight Rules), for an aircraft to fly through complete and thick cloud cover the aircraft and pilot must be IFR rated, even an IFR pilot in an aircraft that is only VFR rated cannot do so.

There is also a concern for any customer who experiences a jump under these conditions. One reply asked would the student mind if they didn't see much? Would they feel "ripped off"? Surely the visuals are part of the skydive for a newcomer who maybe a one off participant? Then of course we have the experienced jumpers who do not need to have the complete visual impact of the skydive, especially if it is a Rel dive where they concentrate on close up grips etc, but they definitely need visuals for tracking, opening and separation under canopy!

70% CIs liked the idea of jumping through cloud in certain conditions, mainly along the lines of the IFR rating allowing aircraft to operate. This was seen mainly for the experienced jumpers but also as a chance to get tandem students jumping in minimal conditions.

Those who liked this idea stressed the criteria that the opening height for jumpers and tandems would have to be below the level of the cloud. Most disliked the idea of exiting in thick cloud all the way down to pull height.

There is also the slim chance of cloud height changing during the climb, so this could be something that is not always guaranteed. On top of this what if we have a high canopy opening? ATC definitely cannot pick this up on radar. If the pilot also cannot see it and report it, then this could also lead to a safety problem.

Of course this leads to the "safety factor" the real issue on everyones mind. What if the regulations were actually changed and we were allowed to jump through 100% cloud cover. Would it be safe? The answer is very dependant on what type of airspace you are using, and how good your pilot/jumpers are at reading the GPS.

All Drop zones would have to go through some kind of inspection to see if they were indeed suitable. Drop zones close to restricted airspace, lanes of entry, water, mountains etc would require special scrutiny as to their suitability.

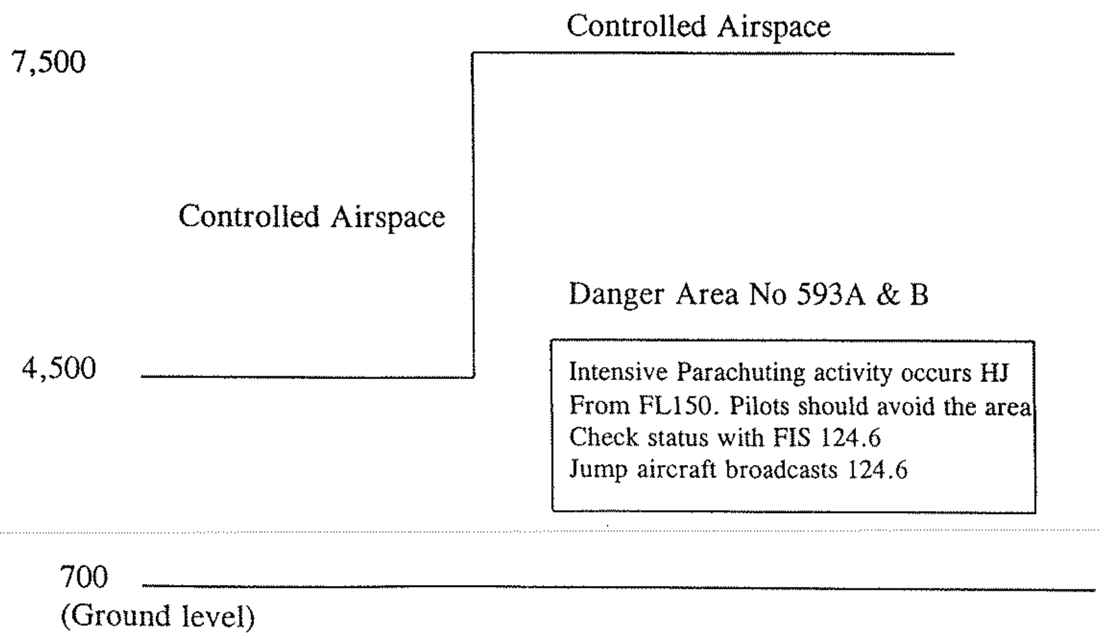
The safest environment for considering this approval would be in complete controlled airspace with a RAS (Radar Advisory Service) as seen in most capital cities. This would ensure that every aircraft that enters the area would have a clearance and a transponder code so that they can be tracked on radar. (Transponders are units in aircraft that are interrogated by ATC radar and shows the aircraft's height and direction whilst in the area of radar coverage. They are required for ALL flights in controlled airspace) Some areas have radar coverage that can actually pick out aircraft that are flying through without transponders.

This would mean that after a "clearance to drop" permission has been received the chances of someone being underneath you on jump run would be virtually eliminated. However, this does not mean that it is impossible for someone to fly into the area without a clearance or without a transponder code! Air space violations are not unheard of and even though the implications for the pilot violating the airspace can be severe.

Despite the small risk, this would seem to be the best way that GPS could be used as a means of jumping through cloud. There has been some mention of using GPS for jumping through cloud in areas such as a CTAF area. This would be one of the worst possible areas for such a test.

CTAF area's are widely used by aircraft who do not possess a radio. Legally they do not require one. This means that any pilot in this area without a radio will use visual look out as the primary means of keeping separation from other aircraft. They will obviously not be flying through cloud but underneath a cloud base where jumpers could be punching through it and this would be a distinct hazard.

Sydney Skydivers have been using GPS for some time and have the following unique airspace considerations around the DZ (all heights AMSL).



For each load the pilot has to obtain five clearances before the drop can go ahead:

1. Clearance from Air Traffic to use the CTA (controlled airspace.)
2. Absence of traffic in airspace outside of CTA (by jump pilot on area frequency)
3. Clearance from DZSO for ground level to cloud base (ensuring airspace free and broken cloud above DZ.
4. Clearance by Radar service from local Airservices
5. Clearance down to cloud top from jumpmaster.

For each load the pilot obtains clearance to drop from the local ATC unit, ATC then monitor the space below for other aircraft and inform the jump aircraft as to whether the airspace is clear. Underneath the controlled airspace (4,000 feet and below) is a local danger area that clearly states "Intensive parachute activity".

Aircraft do not need an ATC clearance to fly in the danger area, all they need to do is to assess the danger to their operation, all aircraft communicate in this area on the area frequency. This is another frequency that the pilot has to monitor and ensure that the airspace is clear before the jumpers fall through it.

The local Airservices unit also require consultation as they can give additional radar information to the jump pilot.

This just leaves the Jumpmaster to check from the aircraft down to cloud top level and the TCO to check from the ground to the cloud base. The TCO is responsible for giving the clear to drop. This should not only entail the TCO outside of the hangar looking at the airspace and watching for traffic. But also by having a radio he can either ask an aircraft to leave the area or if the aircraft is not radio equipped (quite possible!) then get the jump aircraft to go around. This again would be one of the ways that we could make jumping through cloud somewhat safer.

The survey showed the two extreme opinions that existed on the subject. Many were completely against jumping through cloud. Comments such as it will be abused by money hungry operators, students would feel ripped off, and even one CI who thought it was a fatality waiting to happen. Most people wanted to see jumping through cloud with GPS had ideas on how it could be achieved. All mentioned stringent conditions before it could happen.

Some wanted controlled airspace all the way down to ground level, others mentioned bringing Skydiving in line with other aviation sports. If pilots can fly through cloud with an IFR rating (Instrument Flight Rules) why can't skydivers? This would also need to be achieved without it being seen to interrupt or conflict with other air space users.

We would also need to look into a whole new area of what qualifications, if any, a skydiver would need to jump in IFR conditions. Some responses say that IFR ratings for jumpers would be impossible, but then who would have thought some years back that tandem masters would require a private pilot medical? What licence criteria for this IFR rating is something that should be considered. One response to the survey mentions at least a D licence, as people need time in the sport to be exposed to multi skydive experiences.

If we did go the way of IFR flights for parachutists then this would change criteria for Drop zones. IFR pilots can only land IFR equipped aircraft in **complete** IFR conditions on approved airfields. IFR conditions can also be pretty extreme. I would not have thought that in these extreme conditions any type of parachuting activity would be going on at all!

Already there are GPS approaches published at many airfields but some drop zones would find the strict criteria for this totally out of the realms of possibility to achieve. It also slightly changes the criteria for the GPS unit, GPS units for IFR rated aircraft must be TSOed (TSO C129).

This area of a TSO for IFR GPS is open to interpretation. They are required for all IFR navigational flights. If you do not class navigation as taking off from the same airfield as you are landing on then a TSOed GPS isn't required!

In summary the big procedure would be if GPS were to be used as a means of further reducing the minimal conditions that we were allowed to jump in, this would have to be achieved in the safest possible way and may be impossible for high levels of cloud cover for some drop zones with unsuitable airspace around their drop zone. Some drop zones consider themselves lucky that they are outside of controlled and busy airspace, however in the case of GPS this would be a distinct disadvantage.

Criteria for cloud jumping will need to take into consideration items along the following:

1. Type of airspace around the specific drop zone
2. Percentage of cloud cover.
3. Thickness of cloud.
4. Height of cloud.
5. Qualification of TCO for this operation.
6. Qualifications of jumpers on board.

7. Type of operations on board, Tandem, experienced etc
8. Number of passes.
9. Number of jump aircraft on drop zone.
10. Type of ground communications on drop zone.
11. Pilots qualifications and aircraft equipment.

Procedures should cover every eventuality at all altitude levels for the skydive,

The new proposal for jumping through cloud is proposed to take place at Picton. This trial, if it goes ahead, will not cause any noticeable difference to any part of the operation at Picton and has the full support of AOPA (Aircraft Owners and Pilots Association) and Air Services Australia.

With this sort of backing and the chance to prove ourselves then it makes sense to put procedures in place and prove by trial if it is viable AND if CASA will approve it.

*The future of GPS in the sport*

The US President Bill Clinton's GPS policy, in conjunction with IGEB (Interagency GPS Executive Board) is to push GPS satellite technology for future development and world acceptance. This means that GPS is here to stay and will continue to update and expand.

Milestones in our own aviation industry in the last few years include:

*1994 Ref:* *AIP Supplement H18/94*

GPS approved for supplementary navigational aid.

*1995 Ref:* *AIP Supplement H50/95*

GPS approved for primary means IFR navigational aid.

*1998 Ref:* *AIP Supplement H1/98*

GPS approved as supplementary means of IFR non-precision approach navigational aid.

*1998 Ref:* *AIP Supplement H2/98*

GPS approved as primary means of navigation in oceanic and remote area's.

As far as our own part of the aviation industry goes GPS is already used to great effect in our sport, and if used properly will continue to stay. However the rules for its use at present are not specified and we seem to be in the middle ground of how it should be used.

Almost every Chief Instructor (99%) who answered the survey liked the idea of GPS staying as an aid, while most of these CI's also saw the younger generation of jumpers getting used to a pilot spotting the aircraft and stressed that it should be a secondary means of spotting.

Comments include:

1. Yes it's the way to the future as long as aviation is trained well, including jumpers.

2 If handled carefully extremely valuable for all spotting.

3. As big a future as our own personal rig.

Most responses centred around the fact that after just a short while many operators are beginning to see that they cannot do without it. Some state that for larger aircraft operations it is the only way to go, turn around times are quicker and more economical, doors can remain closed until the last minute keeping everyone warmer and keeping the aircraft more economical.

Other responses included how GPS is invaluable at one particular DZ where they have only one run in line due to operations in controlled airspace. GPS makes complying with positioning for ATC requests far more accurate.

Another operator has the Pacific Ocean on one side of his DZ and a town on the other. With ATC and CASA watching closely there is little room for error in certain directions. The GPS makes positioning the aircraft easy here as well. Other DZ's report of strange coastal effects and wind conditions. Again here it is extremely valuable but as in all of the advantages of GPS it is only as good as the pilot or jumper operating it. As some of these drop zone operators have shown there are obviously some very good users of the unit out there.

### *CHIEF PILOT SURVEY*

As pilots have a large part to play in operating GPS in jump aircraft and have a slightly different view point, a much reduced survey was sent to all Chief pilots to ensure that all their opinions and data are included in this thesis.

In particular the survey centred around how much knowledge they had and how they saw the skydivers approach to the unit.

All the pilots surveyed that replied showed a very close split in their level of experience. In fact much of the feedback indicated that pilots experienced with GPS showed a high regard for the equipment (67% said they had at least fair experience with 88% saying it makes flying easier) Whereas those 33% who did not have so much experience tended to say it increased their workload.

Comments include:

1. People who don't use it have "rocks in their heads".
2. Pilot practise and knowledge are important.

Pilots with little experience tended to see it as another piece of equipment in the cockpit to take their mind off of flying the aircraft, particularly when they had other things to concentrate on. As you would expect though as GPS is used so widely most pilots stated they had a high or a fair knowledge on the equipment.

Most of these pilots with experience saw it as a very easy device to use and follow. This would definitely come with currency as well as experience.

In addition experience on local conditions and landmarks played a big part in the response. However it is very easy to see that an inexperienced pilot who is uncurrent and unfamiliar with the local area could tend to be in overload mode, especially with impatient and worried skydivers pushing for information in marginal conditions.

This puts a large responsibility on the Chief instructors or Chief pilots who are responsible for the selection of the jump pilots for the drop zone. Inexperienced pilots should be allowed to concentrate on what they are there for, flying the aircraft and the skydivers in this scenario should be competent and experienced enough to concentrate on their job, particularly spotting.

As far as new pilots are concerned, basic training may come under the banner of the Chief Pilot, just as new pilots have someone with them for the first couple of weekends getting used to local procedures and traffic patterns, then GPS can also be taught and signed off at the same time as obtaining the endorsement for the aircraft. Pilots will need to be proven in it's use before being cleared to fly!

CASA actually state that pilots must be trained in the use of GPS and show theoretically and practically that they can use the equipment before they can use it in IFR flight. There is currently a syllabus in CAO 40.2.1 for this very reason incorporated into ground school. Just another hurdle for our jump pilots if any cloud trial is successful and our pilots need to be IFR rated.

Operating instructions for the GPS must also be incorporated in the flying schools company operating manual, this may mean that our jump pilots procedures must be incorporated into our own club training operations manual?

*Skydivers reliance on GPS*

Over 60% of pilots surveyed saw an extremely high reliance on both the GPS and themselves by skydivers. Again this was only seen as a problem with the more inexperienced pilots. Some comments related to the fact that some skydivers would exit over the ocean if they were told to, due to not having any idea or any interest in where they were. This is the type of observation on our members that we can do with stamping out, even if it is just the minority.

This gives rise to the question of do we sometimes expect too much from our pilots because of our high reliance on GPS for spotting? Most pilots don't mind this extra responsibility, in large aircraft operations it may be the easiest way to go. However other pilots hold those skydivers who just wont tilt their heads a few degrees out of the door in a Cessna in very low regard. Especially the ones who will criticise the pilot for not doing the skydivers job 100% accurately.

Don't forget pilots cannot do everything for us. They need and deserve help from the jumpers on board. Every time a pilot lands and sees canopies landing on the airfield does he know 100% that the spot was good. If the jumpers had to hold all the way down or run all the way down because the spot was either too short or too long, would he really know? Feedback on the spot would help in a big way, just don't always rely on the pilots to do everything for us.

From some of the pilots I have spoken to the message is clear. The GPS usually comes under the pilots banner, but spotting is the responsibility of the skydiver. Work together by all means but look after your own safety and don't be lazy.

**Summary:**

It is quite obvious from the Chief Instructor survey response that the GPS unit is highly regarded with 78% of the respondents seeing it taking over as the main means of spotting.

75% of CIs who responded want to use it for jumping in minimal conditions and 66% want a full official trial in the near future. In addition 95% of replies saw it as having a great future in the sport.

It is in use in every state at a high percentage of Australian drop zones and being used to great effect in most of those areas.

There is some scepticism around but this may be down to the concerns that some senior members have as to the abuse such a system would be given, and also the lack of education that that our younger "new generation" skydiver generally has. Some comments I received on the survey to this effect were:

1. Whether I like it or not the GPS is here to stay, I just hope the quest for the Tandem dollar doesn't kill someone.

2. Useless people benefit from GPS.

3. GPS encourages a "who cares" attitude.

4. It will encourage Greed!

All these comments are valid in the right context and shows the problems we could face if GPS is not implemented properly into our Federations operational regulations and our own members are held accountable as to the conditions that they allow GPS to be used in parachute operations. This includes Chief Instructors, ASOs, drop zone operators and in some cases LDOs.

With the Chief Pilot survey we saw similar view points. Over 80% saw it as an exceptional piece of equipment with over 60% having at least fair experience with it in jump operations.

New revelations in our sport include the advent of the square canopy, the introduction of AADs, especially Cypress, and the AFF programme. All these new fangled ideas were met with some scepticism by many jumpers, but once proven they have become part of our skydiving culture.

If GPS can be implemented properly, accepted by the aviation industry in relation to parachute operations in all conditions, and complete safety procedures implemented to keep the country consistent and safe, then GPS will play a bigger part in the future of our sport.

As GPS is being used across the country with various states of success it is time to start to implement a safe and consistent procedure in relation to parachute operations and GPS.

As mentioned previously our regulations imply that GPS can be used to positively fix our position over the ground, this just needs to be widely known and enforced.

As far as jumping through cloud the first logical step of involving CASA has been achieved and we now need to take the window of opportunity that we have and show that in certain conditions we can be responsible and professional enough to achieve complete safety in these minimal conditions.

GPS will I'm sure play a big part in this trial and show how invaluable it will be in our future.

*Recommendations:*

After receiving all information from the two surveys and taking time to talk to many senior members of the sport my recommendations are:

1. That the GPS continue to be used as a spotting aid.
2. That pilots receive training and be considered competent (via a set syllabus) on GPS before being involved in jump operations.
3. That GPS knowledge is incorporated into the APF licence table so that jumpers are trained in the basics.
4. That instructors be taught proper use of GPS to ensure that they are still in control of exit points and skydiving safety.
5 GPS is restricted to 5 Octa's as per stated VFR flight rules until CASA permits jumping in more marginal conditions.
6. GPS trials with full CASA approval are conducted and all information from these trials disseminated to all drop zones for widespread use and knowledge.

*Annex A*

*Chief Pilot Survey*

*Q1. How Much Experience do you have using GPS in parachute operations?*

*Very little*
*Fair amount*
*High experience*

*Q2. Do you think the GPS makes parachute flying easier for the pilot? Please explain?*

*Q3. How do you rate it as a spotting device?*

*Poor*
*OK*
*Very good*
*Exceptional*

*Q4. Does the advent of GPS put more work on you as a pilot?*

*Yes/No*

*Q5. How much do the parachutists rely on the GPS at your drop zone?*

*Very little*
*Sometimes*
*High reliance*

*Q6. How much do the parachutists rely on it compared to relying on self spotting the aircraft?*

*Less than 50%*
*Higher than 50%*

*If you have any further comments please include them here.*

*Annex B*

*CI Survey*

*Q1. Is the GPS used on your drop zone?*

*Yes/No*

*Q2. If yes, how much do the jumpers rely on it for spotting?*

*Most of the time/some of the time/hardly ever*

*Q3. Do you see the GPS taking over where manual spotting used to be the norm?*

*Yes/No*

*Q4. If yes, does this concern you? Please explain your answer.*

*Q5. Would you like to see a trial conducted in Australia at an appropriate DZ to test it's viability as the main means of spotting?*

*Yes/No Please explain your answer.*

*Q6. Would you like to see GPS used to enable jumping through cloud? Please give reasons for your answer.*

*Q7. Do you see a future for GPS within the sport? If yes in what capacity?*

*Annex C*

*References:*

Publications:

RTCM Recommended standards for Differential NAVSTAR GPS service
GPS Navigation Motorola Communications (Internal)
GPS the Future Motorola Communications (Internal)
GPS 100 Personal navigator handbook.

Aeronautical Information Circulars
Aeronautical Information Publication
Skydiver magazine
Skyline magazine
GPS World magazine
Aviators Guide to GPS by Bill Clarke
Asia Pacific Air safety magazine (BASI publication)

GPS Product bulletin POSNAV
GPS Product bulletin Trimble
GPR Product bulletin Garmin

Plus thanks to:

Brenton Meadows National Sales Manager POSNAV
Gerard Rankin Principle Engineer MacMahon Holdings
Rocco Zito Research Engineer University of Adelaide

*Annex D*

*About the Author:*

Mick Honeyman is the National Site Support Engineer (Data Communications) for Macmahon Technologies in Adelaide SA. He has over 10 years experience with Satellite technology and recent experience with complex data systems using GPS receivers to track vehicles in both production and Search and Rescue applications.

Previously he was a technical rep for Motorola Communications who have been in the GPS manufacturing market since the 1980's.

He is an unrestricted US and Australian Private Pilot and the Display Licence Examiner for SA.