UPGRADING THE CESSNA 206 AIRCRAFT FOR SKYDIVING

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ABSTRACT

Aircraft used in skydiving operations have specific demands placed on them. Most particularly the aircraft is required to climb from take off to the height required for the skydivers to exit the aircraft. The speed and consistent efficiency with which the aircraft climbs to exit height is of particular interest to dropzone operators as it largely determines the cost of operating the aircraft. This thesis undertakes an investigation into the feasibility of various upgrades for Cessna 206 aircraft specifically for use in Skydiving operations. Engine horsepower, exhaust setup, maximum take off weight and airframe modifications are considered when assessing the climb rate benefit of various upgrades. An attempt to compare cost of upgrading versus benefit to dropzone operation is made. It was found that upgrading a standard Cessna 206 to a Cessna 206 with a 300hp engine with a tuned exhaust fitted and wing tip extensions gave a consistent benefit to the drop zone operator and appears a to be a beneficial and justifiable financial expenditure. It was found that when purchasing a used Cessna 206 for skydiving operations a 1974 F model Cessna 206 or later was most appropriate to facilitate aircraft modifications.

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Contents

ACKNOWLEDGEMENTS

An invaluable source of information can be found at the Cessna Pilots Association (1) founded in 1984 and dedicated to single/twin Cessna aircraft. It contains a wealth of information and I found the membership fee a good investment.

In preparing this thesis I consulted many pilots, aircraft mechanics and other people across the world. Among them I would like to thank pilots; Nigel Brennan, Murray Gerraty, Stuart Hills and Dean Munzie. Aircraft mechanics from Mills –Rolfe and Turbo Aero with a special mention to Chief Engineer Scott Sutcliffe. Donna Jones from Davis Aviation services in Tennessee USA provided a wealth of contacts and experience.

I would like to thank the members, past and present, at Commando Skydivers for help and information regarding load times, fuel usage, weight and balance and experiences from their Cessna 206 Aircraft.

INTRODUCTION

This thesis aims to provide an overview of the cost of running the Cessna 206 aircraft and various methods to improve its performance and profitability in modern skydiving operations.

In the current climate of increasing fuel/maintenance prices, the need to get more efficiency from existing aircraft is more important than ever. This thesis provides a broad outline into the history and some of the various upgrades and improvements which are available for the Cessna 206. The basis of developing this thesis has been the work I have undertaken to maintain and upgrade a 1965 U206A, and a 1973 U206F, which required engine rebuilds or replacements as their existing engines had reached the end of their useful life. Having spent hundreds of hours on the internet, phone and personal discussions with pilots, engineers and companies around the world, I felt it would be useful to consolidate in one document a guide to the information and sources I found.

This thesis does not aim to replace any of the manufacturer's documents, aftermarket suppliers' information, or any information supplied via CASA. This thesis does endeavour to provide a starting point to what can be a very complex process. As many dropzone operators are more skilled in running skydiving rather than aircraft operations it was my experience that there was the potential to be overwhelmed by the sheer volume of conflicting information required to be sourced, understood, and acted upon.

Cessna 206 aircraft have been used in Australian skydiving since the early days of our sport. I first jumped from one on jump number 25 on the 9/5/1976 in Commando skydivers VH-RPZ, and 33 years later I am still jumping from them. Despite a trend to larger and faster climbing turbine aircraft, which provide greater altitude and faster cycle times, the venerable old Cessna 206 is still used extensively world wide in our sport. According to ASM magazine drop zone directory, as of early 2009, seventeen are in use at Australian dropzones. The large carrying capacity for their size and large rear door suit smaller operations which do not have the customer base and/or financial strength to justify a larger turbine aircraft.

History of the Cessna 206

Since first produced in 1964 various modifications and upgrades have been developed to increase their range, power and capacity. I have selected those modifications most pertinent to our sport and investigated them in detail in this paper.

Figure 1.0 A timeline of development of the Cessna 206 aircraft.

1963 New model 205 introduced. Essentially a 1963 Cessna 210B with the retractable landing gear locked down in a tricycle undercarriage configuration and changes to crew / passenger doors. Locking the undercarriage down removed the storage bay for the wheels and enabled the floor to be lowered and enlarged.

- Powered with an IO-470-S 260 hp motor.
- Only produced in 1963 – 1964.
- Total built = 576.

1964 Building on the success of the 205, Cessna introduced the 206 as a new type certificate aircraft; designed as a new airplane, not just an upgrade of an older design. In designing the 206, Cessna used a strengthened airframe from the 205 coupled with a larger engine (IO-520-A generating 285 hp @ 2700rpm).Rear double cargo doors instead of the front passenger door and having a gross weight of 1500 kg (3300 lb). In addition the aircraft was certified for flight with cargo doors removed.

1965 Cessna introduced the P206, the P standing for people. This model did not come equipped with double rear cargo doors but was fitted instead with two forward doors and a left aft passenger door. The model 206 with the twin rear doors were designated U for utility. The gross weight for both models remained at 1500 kg (3300 lb). The P206 was named the "Super Skylane" and the U206 the "Super Skywagon".

1966 This year saw the introduction of two turbocharged models, the TU206A and the TP206A. Both models were powered by the TSIO-520-C engine generating 285 hp. Gross weights for all versions increased to 1636 kg (3600 lb). An optional 3 bladed propeller was available and the A at the end of the model designation was added to indicate a model upgrade.

1967 New model B changed the U206 engine to an IO-520-F. Essentially the same as the –A but allowed over revving the engine from 2700rpm to 2850rpm to give an extra 15hp for 5 minutes maximum. P206B remained with the IO-520-A.

1968 P206C and U206C. Larger horizontal stabilizer and elevators.

1969 P206D and U206D. Cosmetic changes only. Introduced 207.

1970 P206E and U206E. Nose wheel cowling modified to eliminate the hump that had been left over from 205 days when the retractable nose wheel was discontinued.

1971 U206E. P206 model stopped production. U206 renamed Stationair.

1972 U206F. Changes include wing leading edge camber increase, larger baggage compartment and cowl mounted landing/taxi lights. No other significant changes through to 1977.

1977	U206G. Turbo charged engine was changed to TSIO-520-M rated at 310 hp for 5 min. then 285 hp continuous.
1978	U206G. Renamed Stationair 6. 28 volt electrical system installed.
1979	U206G. Fuel tanks changed from bladders to integral tanks.
1986	206 production was ended, with a total 5208 U206's and 647 P206's made.
1998	This year saw the restarting of the 206 production line resulting in the 206H using a Lycoming IO-540-AC1A engine rated at 300 hp. This model remains in production to this day.

Establishing a cost of operating a piston engine Cessna 206

To justify any expenditure on an upgrade of any aircraft, first it must be determined what the base cost of operation is. Once this baseline is determined, it is reasonably straightforward to calculate the cost/return ratio and work out the pay back on an investment. There are various factors which effect this calculation. For example, aircraft utilization between summer and winter months and unscheduled maintenance requirements will effect calculations.

Assumptions

The following assumptions are based on my own personal experience working at a dropzone using two Cessna 206's, discussions with pilots and the engineers at our maintenance workshop.

<u>TABLE 1.0</u> Assumptions in establishing a base cost.

Engine Type	IO-520
Exit Height	10,000 feet
Climb time	20 minutes
Descent and taxi time	10 minutes
Engine serviceable life	1700 hours
Loads flown per engine	3400

It is acknowledged that this base cost will vary due to loading, pilot experience, weather conditions, etc. For simplicity I will use what I have found to be a conservative average.

Based on a standard IO-520 engine; a new or refurbished engine has a serviceable life of 1700 hours between rebuild or replacement. (Refer FAA Type Certificate E5CE)

Therefore we can expect to do 3400 loads (1700hrs/ 30 min.) between rebuilds or T.B.O. (Time Before Overhaul)

To purchase and install a factory exchange engine, a reasonable estimate would be AU$50,000 (2). This would give a cost per load of $14.70. ($50,000 / 3400). This is simply the degradation cost of the engine.

In addition to the degradation allowance, there is the additional cost for the 100 hourly scheduled maintenance. This cost can vary considerably, dependent upon various factors, such as the age of the airframe. Newer airframes are likely to have fewer maintenance requirements than older airframes. A conservative estimate of the 100 hourly services would be $3,500. We achieve 200 x 30 minute loads per each scheduled service, leading to an additional ongoing cost of $17.50 per load.

The major cost per load is fuel. Over several years I have noted and discussed our planes fuel usage and have arrived at an average consumption rate of 65 litres per hour (see Appendix I) which relates to 1.0833 liters per min (65/60 = litres/min). With a current bowser price of $1.70 / litre at Moorabbin Airport this gives us a cost for a 30 min. load of $55.25 ($1.70 x 1.0833).

<u>Table 2.0</u> The cumulative costs.

Engine	Cap. Exp./load	Main./load	Fuel/load	Total per load
IO-520-F	$14.70	$17.50	$55.25	$87.45

Note: these figures are based on values current as of early 2009 in metropolitan Melbourne. Although the values will vary in the future, the same calculation method may be used to determine a cost per load value.

There are additional factors associated with the costs of running an aircraft. These include depreciation, insurance, pilot payments, local landing fees, etc. This thesis does not aim to discuss these topics as many dropzones have widely varied local arrangements. Therefore, this thesis is limited to a discussion of hardware costs.

DISCUSSION

Improvements and Upgrades

Improvements and upgrades fall into three key areas, the main being the engine, followed by the airframe, and the propeller.

Type certificate and Supplemental Type certificate

When a U.S. aircraft manufacturer such as Cessna designs a new aircraft it must obtain a "Type Certificate" from the Federal Aviation Authority (FAA). After that aircraft has been produced and released to the market, any changes to that model must be extensively tested before a Supplemental Type Certificate (STC) can be issued. The cost of designing and testing the change is borne by the holder of the STC. To recoup their investment they can then sell the approval to aircraft owners wishing to improve their plane(s). As an example, if you wish to upgrade your engine to a larger one you need to locate and purchase an STC kit for that particular engine on your exact make/ model aircraft before you purchase the engine. Depending upon the change you may be restricted to one supplier or many. Some STC's are only provided by one company who set the price accordingly, but others can be offered by several different companies all with different options and pricing. With most upgrades on aircraft the STC provider sells a complete package with all paperwork and hardware bundled together.

As with any other item you may need it pays to shop around. And don't be afraid to negotiate, these companies are selling products. We saved AU6, 000 on the STC for our engine upgrade by researching.

Benefits of Upgrading

In all areas cost must be compared to benefit by the owner/ operator to determine whether the cost of the upgrade(s) is worthwhile. Using the values calculated in the cost of operating, it can be seen that as little as a 7% decrease in load time would have a marked effect over the course of a year. A saving of two minutes per load (7% of 30 min load) may seem insignificant when viewed in isolation. However, with an average DZ performing approximately 15 loads on a good weather day the minor benefit rapidly escalates into a major benefit. The time saving allows for 15 x 2 = 30 minutes that the plane is not roaring away at near full power chewing up fuel and engine hours. Saving 30 x $1.70 x 1.0833 = $55.25 on fuel alone per day. Conservatively multiplying this by 100 operating days per year gives us a saving of $55.25 x 100 = $5525.00

The benefit of this allows the owner/operator to complete one more load per day using the same staffing levels. The instructors' manifest and management staff are already on site which effectively means that the owner/operator achieves a load for 'free'. When viewed purely from a profitability point of view, this 'free' load provides an additional 7% profit for the day. As well as the obvious cost benefit there is a hidden benefit to the instructor pool of being able to receive greater payment for their days' work, leading to greater employee satisfaction.

Using a 28 minute cycle time on an engine with an effective life of 1700 hours gives a total of 3643 loads (1700x60/28) which equates to an extra 243 loads from the same engine running a 30 minute cycle time. Based on an average 15 loads per day, these loads provide an extra 16 days operating at full capacity from the same expenditure on engine.

Once again, the benefit to the business becomes obvious, as do the follow on staffing benefits.

Considering the benefits when applied to the scheduled 100 hourly maintenance, and using the same formula the effective number of loads between maintenance visits becomes 214, raising from the earlier 30 minute cycle time value of 200 loads between scheduled maintenance.

Table 3.0 The benefits.

Modification	Cap. Exp./load	Main./load	Fuel/load	Total/load
Original	$14.70	$17.50	$55.25	$87.45
Less 7%	13.72	16.36	51.57	81.65

Multiplying this over the course of the engine life gives us 3643 loads with a saving of $5.80 per load = $21,129.40.

Airframe Improvements

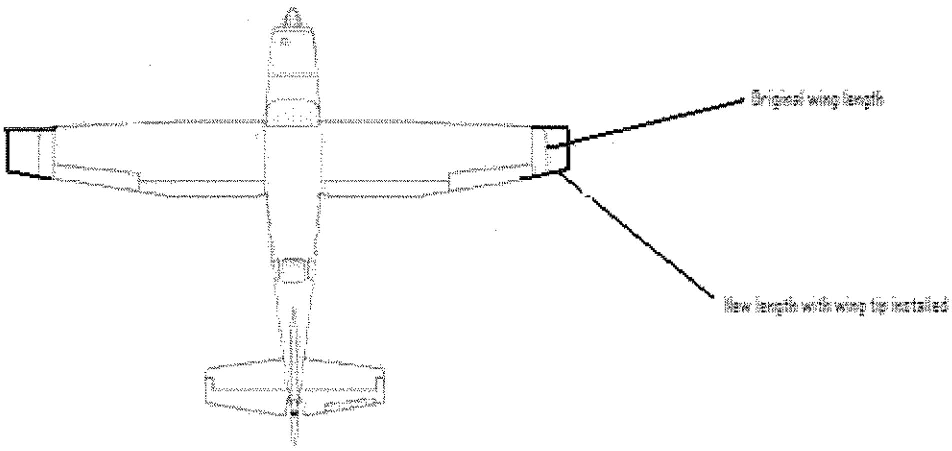
Airframe improvements involve either increasing lift or decreasing drag. In both instances there is a decrease in sortie time, decreasing fuel costs and increasing the number of loads between both 100 hourly and engine rebuild. First off the condition of the airframe has a marked effect on climb rate. Dirt and oil build up, chips and scratches and dents all play a part in spoiling airflow around the skin, causing drag and reducing climb rate. We found after a complete repaint or clean/polish that the planes flew and climbed better.

Airframe improvements include wing tip extensions, wing leading edge camber improvements, flap gap seals and flarings to smooth airflow around the airframe.

If your 206 is pre 1972 then the wing leading edge modification might interest you as Cessna Corp. actually incorporated this modification in the 1972 F model giving those and subsequent 206's slightly better lift and better low speed handling.

All the other performance enhancing modifications I researched did not seem to be supported by solid evidence with the exception of wing tip extensions. These involve fitting 450mm extensions onto the ends of both wings giving an extra 1 square meter of wing area (see Figure 2.0)

<u>Figure 2.0</u> Plan diagram of Cessna 206 wingtip extension modification.



There are a couple of these products on the market ranging from simple fiberglass shells that cost AU$10,000 (3) fitted to long range external bolt on fuel tanks with a fitted price of AU$20,000. My pick are the Flint Aero wing tip tank extensions (4). Although the most expensive way to gain lift they also give an increase in the carrying capacity of the 206 (as detailed in the next section) and are well noted for adding value to your asset if you decide to sell.

Stated increased climb rate is 12-15% and my research found a lot of positive feedback from operators using them. All noted increased climb rates.

Using our initial figure of 20 min. to 10,000' gives us an average climb rate of 500' / min. Using a mean increased rate of climb figure of 13.5% gives us a climb rate of (500 + 13.5%)= 567'/min. This equates to a saving of just over 2 min/load giving us these improved figures.

30 min. - (10,000'/567=17.64minutes climb + 10 min. descent/taxi= 27.64) =2.36 min.

Cap. Exp. 1700 x 60/27.64 = 3690 loads. $50,000/ 3690 = $13.55/ load

Main. /load 100 x 60/ 27.64 = 217 loads. $3500/ 217 = $16.13/ load

Fuel – See Appendix Ib for fuel calculations.

Table 4.0 Cost comparison for wingtip extension modification

Modification	Cap. Exp.	Main/load	Fuel/load	Total per load
Original	14.70	17.50	55.25	87.45
Wing tip ext.	13.55	16.13	46.73	76.41

$11.04 per load - a minor saving when looked at in isolation but multiplied over a year would give us a saving of $16,560.00, repaying our (AU$20,000) investment in 1.2 years or our AU$10,000 in 7 months and thereafter generating savings for the life of the plane.

Also, at our D.Z., we have shown that fitting a solid in-flight door benefits climb rate versus using a fabric door. The fabric door tends to bell out from the fuselage disturbing the airflow and causing extra drag.

M.T.O.W. – Maximum Take off Weight

In its first two years of production, Cessna limited the M.T.O.W. to 3300 lb (1500 kg) and then in 1966 lifted it to 3600 lb (1636 kg). Traditionally the 206 carried six jumpers + pilot per load, however in today's world where people are getting larger and heavier we face the problem of exceeding the weight & balance limits.

According to the Australian Bureau of Statistics (5) the average weight of adults in Australia has increased between 0.5-1kg per year over the past 20 years. If we take the mean as 0.75kg per year then 20 x 0.75 = 15kg. Multiplying this by six jumpers + pilot gives an average weight increase per load of 105kg. Airlines throughout the world are facing the same problem.

At our dropzone, and I have heard the same elsewhere, it has become common to limit the 206 to five passengers to achieve compliance with safety regulations. To work out the useful load of an airplane we take the mtow and deduct from it the measured empty weight of the airframe, the weight of fuel in the tanks and the weight of the pilot. On our clubs average weight & balance sheet for our 1972 206 the mtow is 1636kg, the empty weight is 884kg, our fuel is 70kg and the pilot is 95kg.

1636 – (884 + 70 + 95) = 587kg. This is the useful load that the plane is legally allowed to take off with. Divide this among six geared up jumpers and you have an allowance of 97kg each.

The only method I found to overcome this was to fit the Flint Aero wing tip extension tanks. The STC offered for the U206F and subsequent later series aircraft raises the MTOW to 1727kg (3800 lb), an increase of 91kg (200 lb). Until recently this extra capacity needed to be carried in the wing tanks but that requirement was dropped and the tanks can remain dry and the extra weight carried in the cabin. The wing tanks themselves add 17kg (38lbs) to the empty weight of the airframe giving a useful cabin load increase of 74kg raising the total to 661kg. Divided among six jumpers this gives an allowance of 110kg each. The increase in wing area gives extra lift, reducing climb times and repaying the investment. According to manufacturers claims the modified 206, fully loaded to 1727 kg, climbs the same as an unmodified 206 fully loaded to 1636 kg.

Propeller

Propeller technology could easily take up several pages but simply put most 206's use either a McCauley or Hartzell (6) 3 blade 80" propeller due to the slightly better rate of climb, smoothness, noise reduction and lower maintenance compared to the original two blade propeller fitted. The latest technology is the new generation Scimitar style blades which incorporate rounded blade tips to reduce noise. These propellers purportedly achieve the same climb rate or better compared to current style propellers with the added benefit of reduced noise. The noise reduction side of these propellers is noted around the world but the claims of climb rates are not so well supported. We fitted a Scimitar propeller to our 206 in an effort to reduce the sonic crack from the IO-520-F engine increasing the propeller tip speed through the sound barrier on take off.

The noise level did reduce but, compared to the McCauley 3 blade propeller that it replaced, we felt that the climb rate did not increase; in fact we are starting to believe it has reduced slightly. We are planning on running time tests to clarify this. Skydiving aircraft spend most of their time climbing at high power, so noise can become an issue with neighbors. Minimizing conflict with neighbors and having positive community relations adds value to the profitability of an operation. For further technical information (7)

Engine

When considering engines, the skies the limit! Everything from turbine to turbo to larger piston engines.

Most 206's still operate on their original 285 hp Continental engines, either the straight –A which provides 285 hp @2700 rpm., or the –F which is able to generate 300 hp @ 2850 rpm for 5 min. (max.) before dropping off to 285 hp @ 2700 rpm.

Note: regarding the increased horse power offered by the IO-520-F engine. The increase of 15 hp is gained by increasing the rpm of the engine. This however leads to the problem of the propeller turning faster causing the propeller tip to break the sound barrier resulting in a sonic crack. The sonic crack generates excessive noise and disturbs the airflow over the propeller resulting in a loss of some of the additional horsepower. In addition propellers are designed to operate most efficiently in a small range of rpm. Increasing the rpm of the propeller takes it beyond its most efficient range and a lot of the additional horsepower is lost. (8)

Engine Rating Standards

Upon investigation it was found that the old standard of rating aircraft engines (Part 13, Civil Air Regulations, June 15 1956) allowed a +/- 2.5% tolerance on the actual horsepower output of the engine. An engine rated at a nominal 285 hp could easily have an actual output of only 277 hp. The rating was done without accessories fitted (alternator, air conditioning, vac. pump) If we allow for 3 hp to drive the accessories (ignoring air conditioning.), it can be seen that the actual available hp could easily be as low as 274 hp, with the maximum as 289 hp (285 + 2.5% - 3)

The new rating system (FAR 33.45/49 – Feb. 1 1965) stipulated that the stated horsepower must have a tolerance of between -0% to +5% with accessories fitted. Manufacturers ensure this rating is achieved by slightly over engineering the design to ensure that an entire production run meets the required limits so as to avoid scrapping the run due to a marginal rating.

It is possible to see that changing an engine IO-520 (274hp to 289 hp) rated under the old system to an engine IO-550 (300hp to 315hp) rated under the new system would give a guaranteed 15 hp (5%) minimum increase, with a more likely increase being in the order of 20-30 hp (10%).

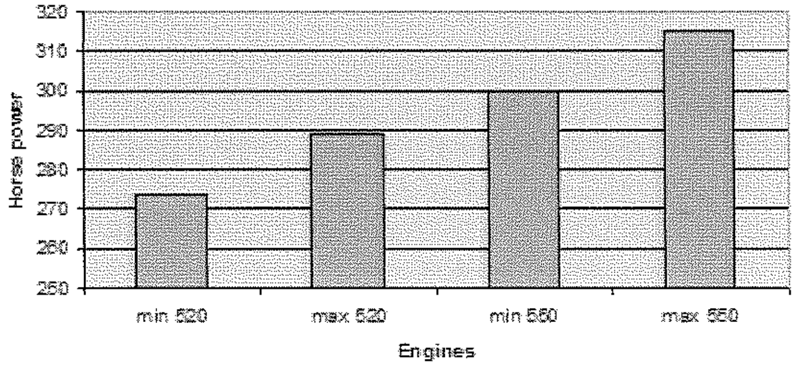
Looking at the diagram below showing the minimum and maximum ranges of these engines we can calculate the mean improvement as 26 hp.

IO-550 mean (315 + 300) / 2 = 307.5

IO-520 mean (289 + 274) / 2 = 281.5

307.5 – 281.5 = 26 hp mean increase

Figure 3.0 Horsepower variations from engine stated value.



All the figures used are for maximum power at sea level. Due to air pressure reducing as altitude increases the available oxygen to the engine also reduces. This reduction in oxygen affects the power output of the engine. A general rule of thumb, as all pilots are taught, is a reduction in power of 3.5% per 1,000'. This rule applies to all non turbocharged piston engines.

Terminology - Continental motors.

I = Fuel injected

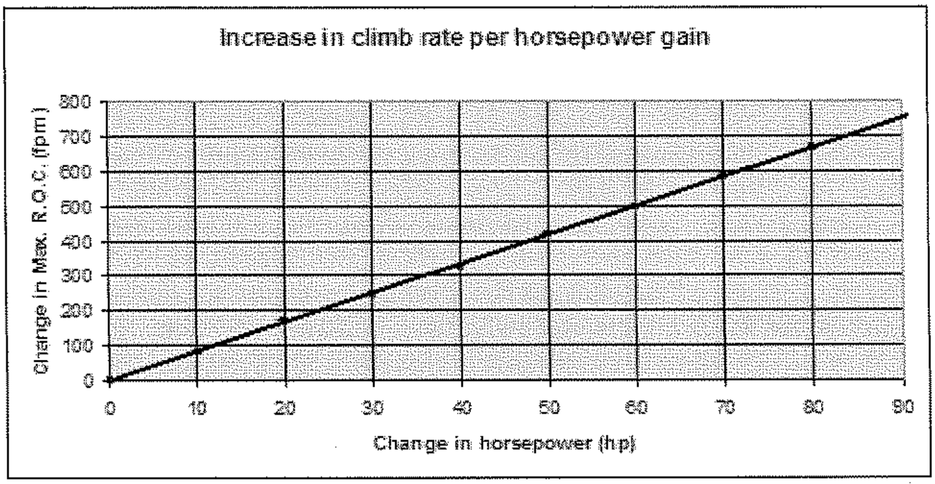
O = opposed cylinders

T = turbo

G = geared

With the 520 or 550 being the cubic inch measurement of the engine.

Figure 4.0 Horsepower versus Rate of Climb



The above graph shows the benefit in increased rate of climb for a given increase in horsepower from an engine upgrade. The increase rate is 8.3' / min for every horse power gained. From this we can calculate the saving achieved per load or hour and calculate the return on investment, the cost/benefit analysis. (9)

Piston Engine upgrades

IO-550-F - 300 h.p.

Converting existing IO-520 engine

The older type IO-520 285 hp engines can be converted to IO-550 300 hp by increasing the stroke of the piston from 4" to 4.25". This is done by changing the camshaft and connecting rods, usually during an engine rebuild when time expired.

We looked at this option for our first upgrade but decided against it due to many reports of cooling and cracking problems with the older style engine blocks coping with the added heat generated by the increased horsepower.

Buying new or exchange engine

The upgrade to this tried and proven engine has been available for decades. Beech Bonanza operators also use the same IO-520 engines and many of them have upgraded to this engine. Hundreds of testimonials from them and 206 operators around the world praise this engine. Due to its solid reputation this is the engine we at Commando Skydivers chose to install in our 206. Several companies provide the S.T.C. kits in various forms and prices (10) for all models. Approx. cost is AU$60,000 (2)

Advantages;

- 300 hp continuous @ 2700 rpm unlike the IO-520-F which is limited to 300 hp for five minutes max. @ 2850 rpm
- Mean increase of 26 hp over original IO-520
- Increase in Max. Rate of climb of 216 ft/min
- Tried and proven over many years in many makes of aircraft.
- If buying new/refurbished, better cooling engine design than the IO-520

Disadvantage

- If modifying IO-520 then cooling issues need to be addressed

Table 5.0 Cost comparison for IO-550-F 300hp engine

Engine	Cap. Exp.	Main./load	Fuel/load	Total per load
IO-520	14.70	17.50	55.25	87.45
IO-550-F	14.12	14.00	41.85	69.97

See Appendix II for fuel usage figures.

At a saving of $17.48/load multiplied over a 1700 hour engine gives us a payback figure of $74,290. (1700 x 60 / 24) x $17.48

IO-550-N 310 h.p.

Atlantic Aero (11) based in North Carolina, USA have developed an STC to install this engine into all C206's produced from 1974 - 1986. This version of the IO-550 engine uses an improved air intake system to boost the horsepower from 300 to 310 hp.

Advantages;

- 310 hp continuous @ 2700 R.P.M.
- 2000 hour T.B.O. (643 more 28 min. loads for same engine expenditure as IO-550-F)
- Mean increase of 36 hp over original IO-520
- Increase of Max. Rate of climb of 299 ft/min
- Runs cooler than IO-550-F
- Same engine price as IO-550-F – AU$60,000 (2)

Disadvantages;

- Much newer upgrade than IO-550-F so very little information on potential problems or benefits from independent sources.

<u>Table 6.0</u> Cost comparison for IO-550-N 310hp engine

Engine	Cap. Exp.	Main./load	Fuel/load	Total per load
IO-520	14.70	17.50	55.25	87.45
IO-550-N	11.35	13.26	38.25	62.86

See Appendix III for fuel usage figures

At a saving of $24.59/load multiplied over a 2000 hour engine gives us a payback figure of approx. $129,982. A good investment but associated with the risk of an unknown quantity in that little, if any, independent data is available on this motor used in a 206 outside of manufacturers claims.

TSIO-540-J2BD 350 h.p.

Aeromods (12) in Nevada, U.S.A. provide an S.T.C. to install this engine into C206's from model A to G.

Advantages;

- 350 hp continuous @ 2700 R.P.M.
- Turbo charged so power continuous to height
- Mean increase of 76 hp over original IO-520
- Increase of Max. Rate of climb of 631 ft/min

Disadvantages;

- Complex change involving structural changes to airframe
- Company not very interested in doing business in Australia.
- Approx. AU$120,000 investment

<u>Table 7.0</u> Cost comparison for TSIO-540-J2BD 350hp engine

Engine	Cap. Exp.	Main./load	Fuel/load	Total per load
IO-520	14.70	17.50	55.25	87.45
Lycoming 540	13.46 *	19.00	29.24	61.67

See Appendix IV for fuel usage figures   * See Appendix IVb for conversion price breakdown

At a saving of $25.78/load multiplied over a 2000 hour engine gives us a payback figure of $162,800. After deducting the upgrade costs of AU$35,000 still leaves a return on investment of $127,800.

Tuned Exhaust System

While on the topic of piston engines we also fitted tuned exhaust systems to both our 206's. (13) Our research indicated that the manufacturer's claim of giving back 10 hp normally lost to imbalance in the exhaust system was correct. Also I had paid several large invoices over the years for welding repairs to the exhausts and had been looking for a higher quality /lower maintenance replacement. After fitting the exhaust systems the majority of our pilots indicated they could feel an increase in the power.

Diesel Engines

In Europe the move is toward highly economical diesel technology for cars. This technology shows high reliability, low noise / emissions and plentiful power. With this, came the question – Why couldn't planes have the same benefits?

Diesel engines are not a new concept for aircraft. The first recorded use of diesels in aircraft was in 1928 with the Packard radial diesel (14) Looking at general aviation, the first manufacturer to produce a certified engine is Thielert (15) with a turbo diesel. Retrofit kits are available for the

206 and they have shown what can be achieved applying modern engine technology to old but robust airframes. Fully laden climb rates of 1,000' + / min, fuel economy nearly double that of the aging existing piston engines, Jet A1 or diesel fuel. Cessna Corporation already offer a Thielert diesel option and at least three other manufacturers (16) are close to finalizing diesel turbo engines for GA aircraft so the next five years should be interesting.

Most of the diesel engines under test operate at higher rpm's than normal aircraft piston engines. The power is delivered to the prop via a reduction gearbox and contrary to established practice, it is water cooled.

As an option for a potential engine upgrade we decided that the technology was too new and unproven over a long period to warrant inclusion at this time.

Turbine

If you have a 1977 or later 206 then this upgrade would give you one of the fastest climbing 206's in the world at 1900'/ min. fully loaded. This is achieved by using the 420 hp Rolls-Royce 250-C20S geared turbine engine; Soloy Aviation Solutions (17) have created what is possibly the world's best small D.Z. jump ship but also the most expensive. With a price tag for the kit running at US$500,000 you would need a plentiful supply of customers to repay this investment. Several dropzones in Europe are currently using this conversion so they must feel that the investment is worthwhile.

Table 8.0 **Cost comparison for turbine engine**

Engine	Cap. Exp.	Main./load	Fuel/load	Total per load
IO-520	14.70	17.50	55.25	87.45
Turbine	26.43	17.50	27.90	71.83

See Appendix V for fuel usage figures * See Appendix Vb for conversion price breakdown

At a saving of $15.62/load multiplied over a 3500 hour engine gives us a payback figure of $218,680. After deducting the upgrade costs of $380,000 we have a net loss of $161,320. The upgrade costs would need to be paid back over two engine life cycles.

CONCLUSION

If looking to buy a used 206 for skydiving then an F model (1974) or later would be the best choice. The increased gross weight, better takeoff power, larger elevators, nose wheel hump removed for more streamlined shape and wing camber increase giving better lift. Furthermore most upgrades that would increase its power or climb require an F model or later.

All the research I have done points to Flint wing tip tanks as a big positive for a skydiving Cessna 206. If looking to buy a used plane then this would be up the top of your shopping list. To install as an upgrade they are a low maintenance investment that will generate extra income every load and they will add to the resale value of the plane in the event of selling. If extra carrying capacity is not an issue then the cheaper fiberglass wing tip extensions (without tanks) would generate the same increased lift.

The following tables consolidate the information in previous sections. If you are looking for the fastest load times then the Soloy turbine would be your choice. For economy and value then the IO-550-N comes out in front, however it does not as yet have a solid history of performance in the 206, so a considered choice must be made. For a lower improvement but with gold credentials then the IO-550-F is a logical choice. It gives nearly 10% improvements in performance and is backed by a solid reputation.

Table 9.0 Cost comparisons for different upgrades.

Engine	$ /load/TBO	$/load/100hr	$/load-fuel	Total $/load
IO-520	14.70	17.50	55.25	87.45
IO-550-F	14.12	14.00	41.85	69.97
IO-550-N	11.35	13.26	38.25	62.86
Lycoming 540	13.46	19.00	29.24	61.67
Turbine	26.43	17.50	27.90	71.83
Wing tip ext.	13.55	16.13	46.73	76.41

Figure 5.0 Cost comparisons for different upgrades.

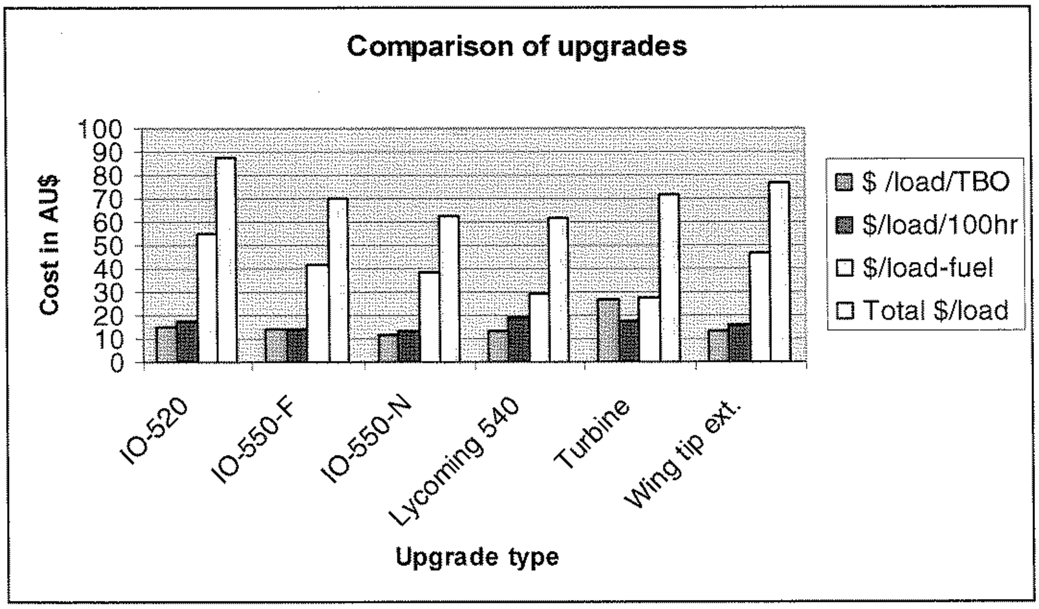


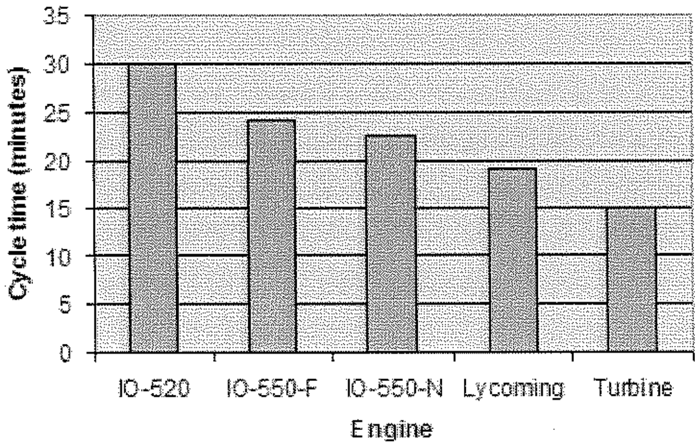
Table 10.0 Main factors for consideration with each engine type.

Engine	Cost Au $	TBO (hours)	Increase in climb
IO-550-F	60,000	1700	210'/min
IO-550-N	60,000	2000	290'/min
Lycoming 540	120,000	2000	600'/min
Turbine	750,000	3500	1400'/min

Table 11.0 Cycle times comparisons for different engines.

Engine	IO-520	IO-550-F	IO-550-N	Lycoming	Turbine
Cycle time	30 min	24 min.	22.5 min.	19.00 min.	15 min.

Figure 6.0 Cycle times for different engines



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Appendix I

Fuel usage IO-520 engine.

Fuel usage measured in Max. Climb 22 gal/hr which converts to 83 litres/hr. (1 gallon = 3.785 litres) or to 1.38 litres/min. 20 min. climb x 1.38 = 27.67 litres used in total climb. On descent fuel usage = 4 gal/hr which converts to 15 l/hr which converts to 0.25 litres/min. 10 min descent/taxi = 2.5 litres total

27.67 + 2.5 = 30.17 per load x 2 = 60.34 litres per hour. We round up our usage figure to 65 l/hr for costing purposes to allow for hot days, time on hold due to air traffic, etc.

Ib

Wing tip extension fuel usage

Using above figures for climb and descent fuel usage

New climb time = 17.64 min x 1.38 litres/min = 25 litres climb + 2.5 litres descent = 27.5 litres x $1.70/ litre = $46.73 per load

Appendix II

Original baseline maximum rate of climb of IO-520 engine = 500' / min.

Using graph Figure 4 to calculate increase @ 26 hp = 216' / min + 500 = 716' / min.

10,000' / 716 = 14 minutes. Add descent time of 10 min. = cycle time = 24 min.

Fuel usage IO-550-F

Over a years operation we have noted an increase in fuel usage with the larger engine to 95 litres/hr on climb which = 1.58litres/min for 14 min = 22.12 + 2.5 descent = 24.62 litres x $1.70 = $41.85

Appendix III

Original baseline maximum rate of climb of IO-520 engine = 500'/min.

Using graph Figure 4 to calculate increase @ 36 hp = 299'/min + 500 = 799'/min.

10,000 '/ 799 = 12.5 min. Add descent time of 10 min. = cycle time = 22.5 min.

Fuel usage IO-550-N

Manufacturers claims of better fuel economy are unsupported as yet by independent sources so I chose to leave the usage figure the same as the –F engine in Appendix II.

Climb time = 12.5 min x 1.58 litres = 20.00 + 2.5 = 22.5 x $1.70 = $38.25

Appendix IV

Original baseline maximum rate of climb of IO-520 engine = 500' / min.

Using graph Figure 4 to calculate increase @ 76 hp = 631' / min + 500 = 1131' / min.

10,000' / 1131 = 9 minutes. Add 10 min. descent = cycle time of 19 minutes.

Fuel usage Lycoming 540

Sourced from manufacturer's fuel usage plus supportive evidence from use on Piper Navaho.

98 litres/hr on climb = 1.63 litres/min x 9 min = 14.7 0 + 2.5 litres descent = 17.20 litres x $1.70 = $29.24

Appendix IVb

Cost used in comparison

The conversion price of AU$120,000 is comprised of three components;

1/ cost of the engine – AU$85,000 (8a)

2/ conversion kit – AU$15,000 (10)

3/ labor component – AU$20,000 (10)

For the purpose of this comparison I have only used the purchase price of the engine as the converted 206 has not degraded and merely needs the engine rebuilt.

Appendix V

Fuel usage Turbine

Soloy provided figures of 7.5 min. to 10,000' fully loaded with a max fuel rate of 120 litres/hr. This gives us a figure of 120/60 = 2 litres/min x 7.5 min. = 15 litres climb + 3 litres descent = 18 litres x $1.55 (Jet A1) = $27.90

Appendix Vb

Cost used in comparison.

The conversion price of AU$750,000 is comprised of three components;

1/ cost of the engine – AU$370,000

2/ conversion kit – AU$294,000

3/ labor component – AU$86,000

For the purpose of this comparison I have only used the purchase price of the engine as the converted 206 has not degraded and merely needs the engine rebuilt.