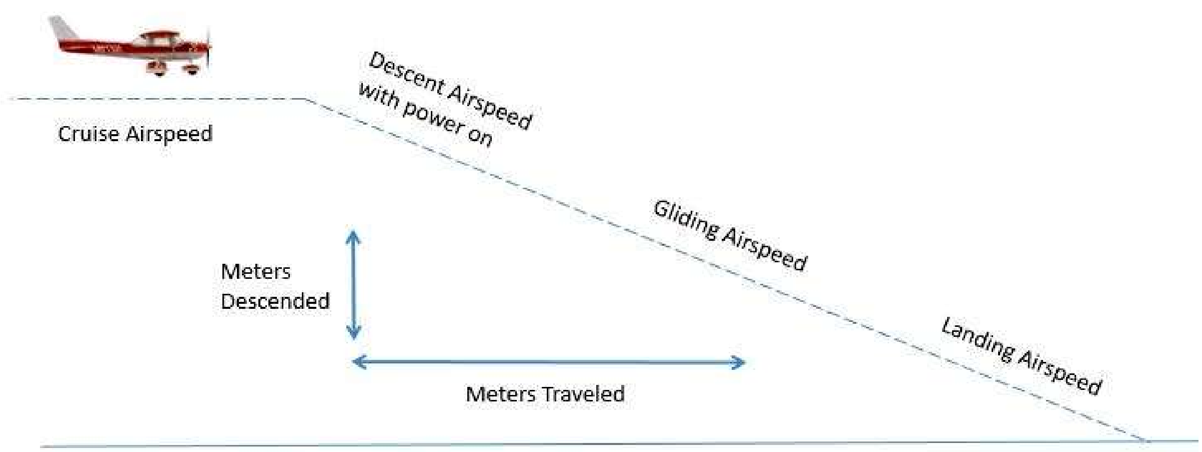
Introduction

These instructions cover a basic auto landing setup. They present sections on knowing your airplane's flight characteristcs, flight planning, landing parameters, and auto flaperons. They also cover setting up and using airspeed and rangefinder sensors.

Your ArduPlane autopilot will achieve good and repeatable landings using these basic setup values. There are more landing control parameters described in the ArduPlane documentation to further refine your landings once you gain experience with these.

Know Your Airplane

The first step is to know the flight characteristics of your model. Make some test flights where you perform level cruising flight under power, descending flight under power, gliding descents, and flared landings.



Also note the distances traveled while descending so you can determine a representative glide slope. For example, if the plane descends 1 meter for every 20 meters traveled the glideslope is 1/20 = 5%. Here are some typical flight characteristic numbers:

- 11 meters per second (m/s) cruising speed
- 9 m/s descent speed while at low power, 3% glide slope
- 8 m/s descent speed while gliding, 4% glideslope
- 7 m/s descent speed when flared for landing
- 5 degrees pitch angle when flaring

Given these numbers here is the general procedure that the autopilot will use to land the plane:

1. Come around to your final heading at the start of the landing approach, lower the flaps and reduce speed to 9 m/s

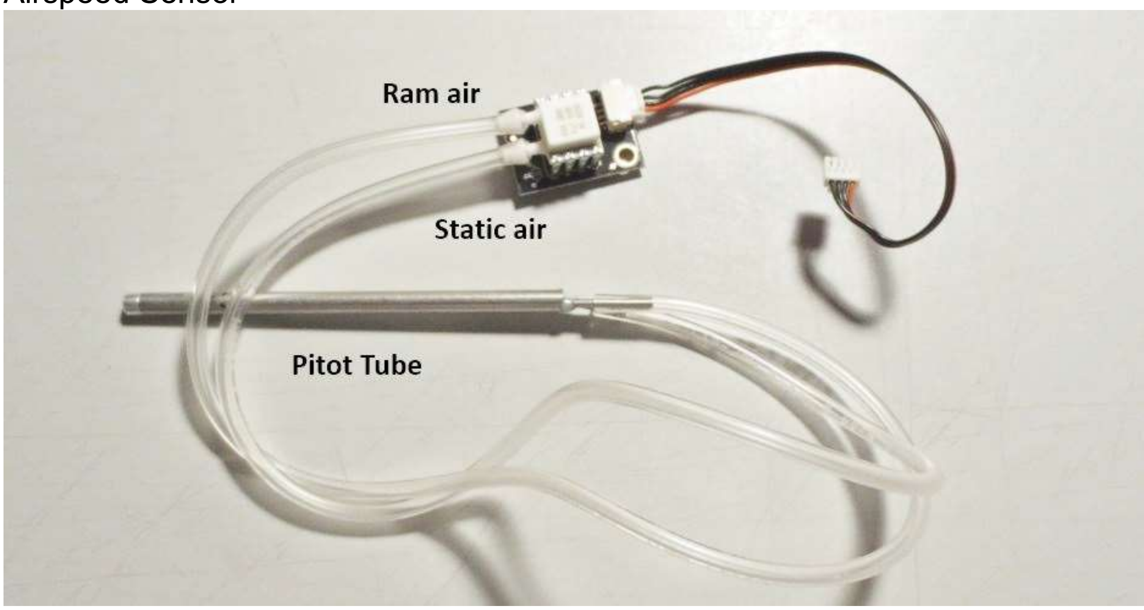
2. At an altitude of 3 meters, reduce speed to 7 m/s

3. At an altitude of 1.5 meters, flare with a minimum pitch of 5 degrees

Required Equipment

ArduPlane's landing algorithms can achieve good auto landings using the autopilot's barometric altimeter for altitude and GPS for estimating airspeed. However, for more accurate and repeatable results, you must add an airspeed sensor. The airspeed sensor provides real-time airspeed data to the algorithm which improves accuracy.

Airspeed Sensor

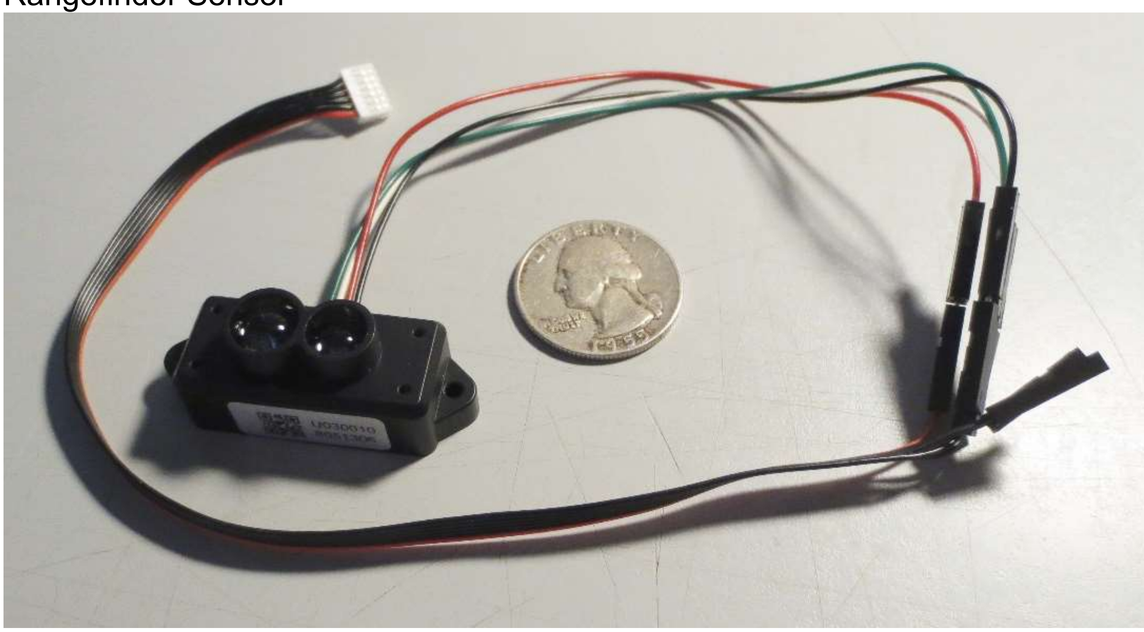


The airspeed sensor's pitot tube gets mounted facing forward out of the prop wash. Here we see one on the wing's leading edge.

Pitot Tube

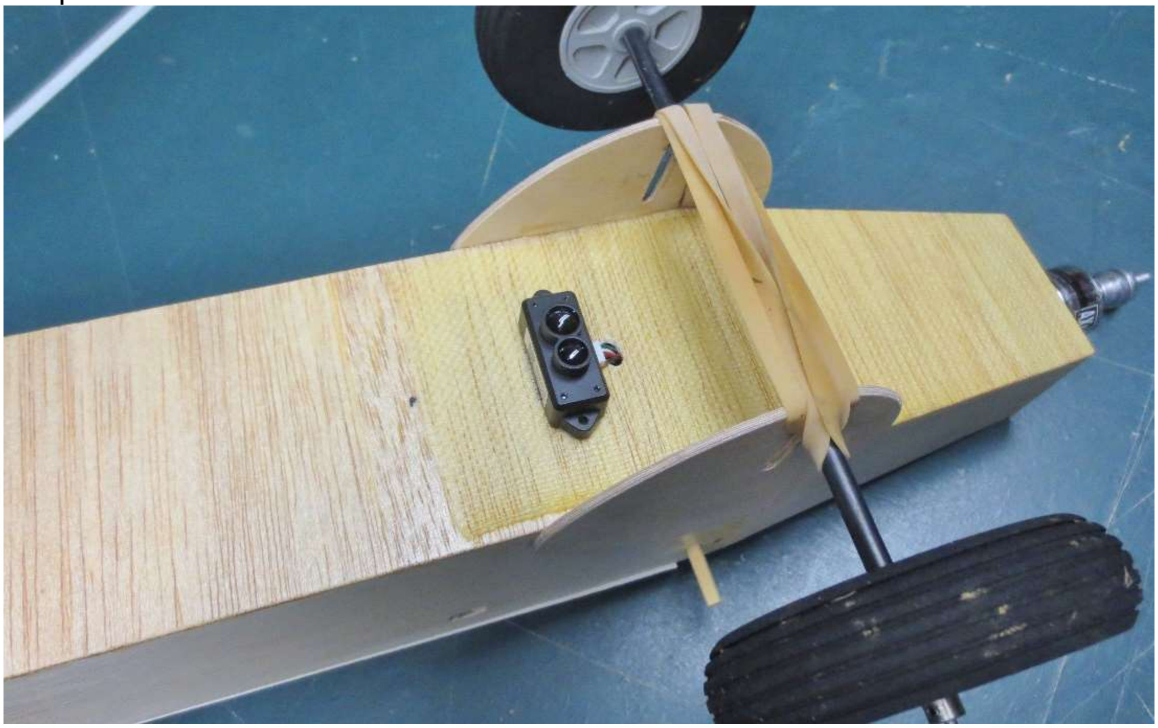
While the autopilot's barometric altimeter works surprisingly well, it is subject to errors due to changing weather conditions and uneven terrain at low altitudes. Since we want accuracy at low altitudes for landing, add a rangefinder sensor. I used an inexpensive unit called the TFMini which gives reliable distance readings from 1 to 6 meters.

Rangefinder Sensor



The airspeed sensor gets mounted facing downward directly at the ground.

Airspeed sensor mounted

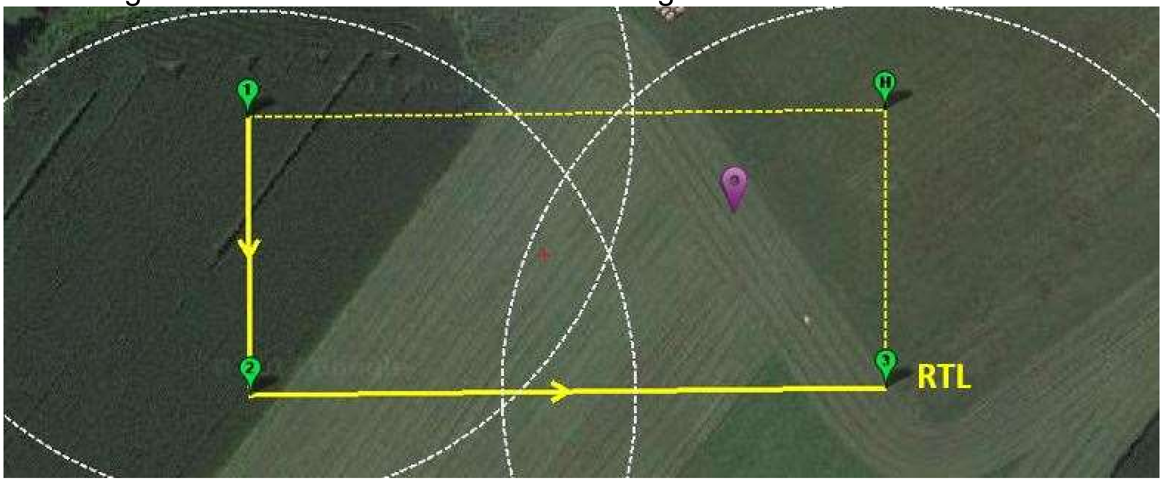


The next sections show how to add landing instructions to a Mission Planner flight plan and how to configure the autopilot landing parameters. The flight plan manages the geographic position and altitude of the plane during the cruise portion of the flight and the landing parameters tell the autopilot how to control the airspeeds, descents and flare during the landing approach.

Landing Approach

We will start with a basic Mission Planner flight plan and then add an auto landing to it. In the basic plan we used a Return To Home (RTL) command at the third waypoint WP3 to tell the airplane to fly back to the home location H or to the nearby rally point. Then we land the plane manually.

Basic Flight Plan with RTL and Manual Landing

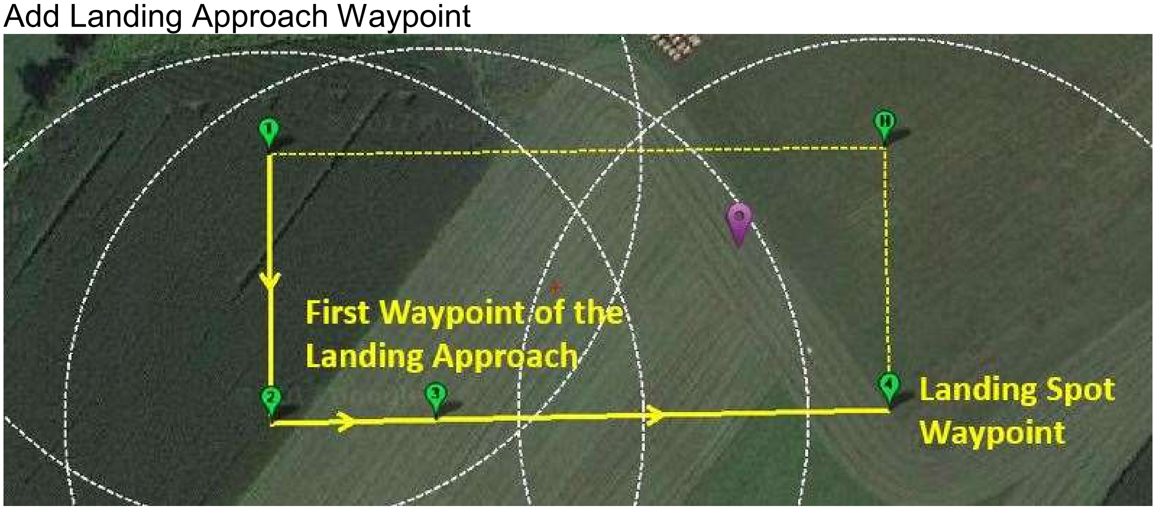


Now we will modify this basic plan to end with an auto landing instead of a RTL and manual landing.

Step 1 – Add Landing Approach Waypoint

Insert a new waypoint WP3 that aligns the plane between the last cruising waypoint WP2 and spot where you want to land, in this case waypoint WP4. Assign an altitude to WP3 that enables the plane to descend using its natural glide slope towards the landing spot.

Add Landing Approach Waypoint



Note that waypoints 2, 3, and 4 are lined up. This makes it easier for the autopilot to keep the plane on the approach track as the landing algorithm limits the bank angle when the plane is close to the ground.

Step 2 – Add the Landing Start Marker

The landing start marker is a command called DO_LAND_START that we insert into the flight plan as seen at line 3 below. Place the command before the waypoint that you designate as the beginning of the landing approach.

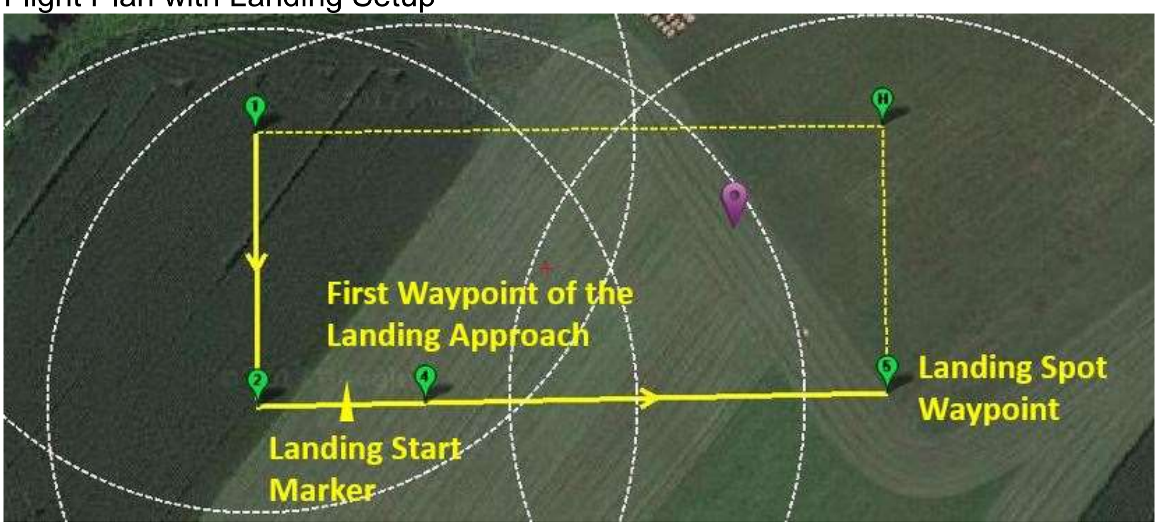
Mission Planner Flight Planner

	Command		Acc radiu	Pass by		Lat	Long	Alt	Delete	Up	Down	Grad %
1	WAYPOINT	0	0	0	0	779989	7849333	60	X			3.8
2	WAYPOINT	0	0	0	0	7794122	784928	40	X			-2.9
3	DO_LAND_START	0	0	0	0	0	0	0	X			0.0
4	WAYPOINT	0	0	0	0	7794203	7844613	25	X			-3.5
5	LAND	0	0	0	0	7794406	7831738	0	X			-2.1

The DO_LAND_START command uses a numbered row in the plan but does not show up on the map view. On the map you can deduce that the marker is present because the WP numbering skips from WP2 to WP4. The landing spot is now WP5.

Also note the value called Grad % on the right of the plan. The number represents the glide slope as meters descended versus meters traveled forward. Adjust the distances and altitudes on the map plan to get close to your desired glideslope. If it is too steep the plane may speed up and overshoot the landing spot. If it is too shallow the plane may carry power up to the flare point. You will eventually find the best glide slope through experimentation.

Flight Plan with Landing Setup



The landing start marker tells the autopilot that the next waypoint WP4 is the official start of the landing approach. The start of the landing approach is where and when the landing controls come into play.

Landing Controls

The landing controls include a set of parameters that dictate the airspeeds, glide slopes, and pitch angles used to complete the landing. There are also additional parameters that can deploy landing flaps and adjust the plane's sink rate during the landing flare.

The landing controls divide the landing into three stages:

- **Landing approach**. At the start of the landing approach the autopilot slows the plane down to a descent airspeed defined by the TECS_LAND_ARSPD parameter. This airspeed should be slow enough to descend but not too slow to cause a stall. Also at the start of the landing approach the autopilot can also lower the flaps by an amount defined by the LAND_FLAP_PERCNT parameter.

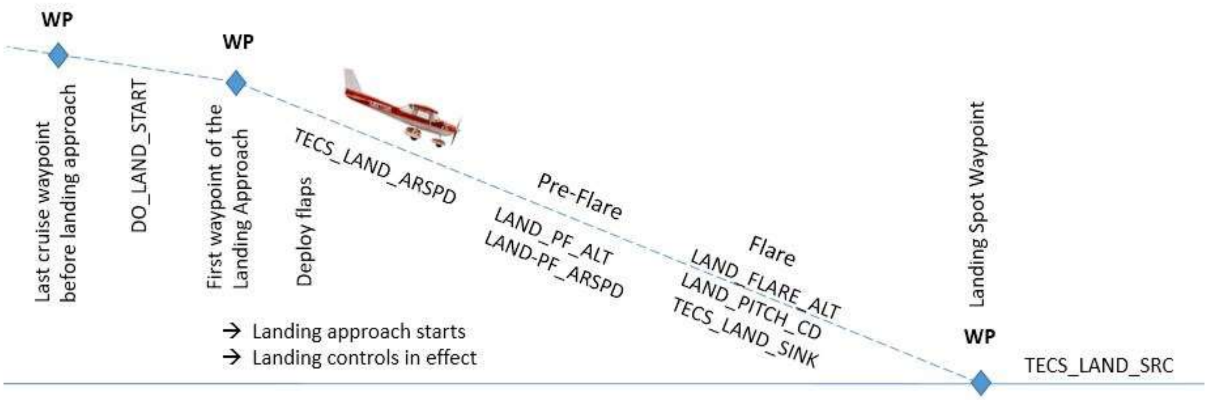
- **Pre-Flare**. This second landing stage provides the opportunity to specify another, slower airspeed as the plane gets closer to the ground. This slower airspeed is set by the LAND_PF_ARSPD parameter. The pre-flare stage is triggered when the plane descends to an altitude specified by the LAND_PF_ALT parameter.

- **Flare**. The third and final landing stage is the flare. The flare is triggered when the plane descends to an altitude specified by the LAND_FLARE_ALT parameter. During the flare, the motor is cut and the heading gets locked in towards the landing spot.

  During the flare the autopilot will raise the nose to a minimum amount set by the LAND_PITCH_CD command. The TECS_LAND_SINK parameter defines the sink rate that the autopilot attempts to achieve during the flare. Finally, the TECS_LAND_SRC parameter tells the autopilot to increase the sink rate if the plane overshoots the landing spot.

The diagram below summarizes the key landing control parameters and where they apply during the auto landing.

Auto Landing Sequence



Here are the parameters with values from our example as you enter them in Mission Planner's Configurations and Tuning section. The rest of the landing-related parameters that are not shown are left at their default values. This is with ArduPlane version 3.8.5.

Auto-Landing Parameter Values

Command	Value	Units	Options	Desc
LAND_FLAP_PERCNT	50	Percent	0 100	The amount of flaps (as a percentage) to apply in the landing approach and flare of an automatic landing
LAND_FLARE_ALT	1.5	meters		Altitude in autoland at which to lock heading and flare to the LAND_PITCH_CD pitch. Note that this option is secondary to LAND_FLARE_SEC. For a good landing it preferable that the flare is triggered by LAND_FLARE_SEC.
LAND_PF_ALT	3	meters	0 30	Altitude to trigger pre-flare flight stage where LAND_PF_ARSPD controls airspeed. The pre-flare flight stage trigger works just like LAND_FLARE_ALT but higher. Disabled when LAND_PF_ARSPD is 0.
LAND_PF_ARSPD	6	m/s	0 30	Desired airspeed during pre-flare flight stage. This is useful to reduce airspeed just before the flare. Use 0 to disable.
LAND_PITCH_CD	800	centi-Degrees		Used in autoland to give the minimum pitch in the final stage of landing (after the flare). This parameter can be used to ensure that the final landing attitude is appropriate for the type of undercarriage on the aircraft. Note that it is a minimum pitch only - the landing code will control pitch above this value to try to achieve the configured landing sink rate.
TECS_LAND_ARSPD	8		-1 127	When performing an autonomus landing, this value is used as the goal airspeed during approach. Note that this parameter is not useful if your platform does not have an airspeed sensor (use TECS_LAND_THR instead). If negative then this value is not used during landing.
TECS_LAND_SINK	0.25		0.0 2.0	The sink rate in meters/second for the final stage of landing.
TECS_LAND_SPDWGT	1		-1.0 2.0	Same as SPDWEIGHT parameter, with the exception that this parameter is applied during landing flight stages. A value closer to 2 will result in the plane ignoring height error during landing and our experience has been that the plane will therefore keep the nose up – sometimes good for a glider landing (with the side effect that you will likely glide a ways past the landing point). A value closer to 0 results in the plane ignoring speed error – use caution when lowering the value below 1 – ignoring speed could result in a stall. Values between 0 and 2 are valid values for a fixed landing weight. When using -1 the weight will be scaled during the landing. At the start of the landing approach it starts with TECS_SPDWEIGHT and scales down to 0 by the time you reach the land point. Example: Halfway down the landing approach you'll effectively have a weight of TECS_SPDWEIGHT/2.
TECS_LAND_SRC	0.3	m/s/m	-2.0 2.0	When zero, the flare sink rate (TECS_LAND_SINK) is a fixed sink demand. With this enabled the flare sinkrate will increase/decrease the flare sink demand as you get further beyond the LAND waypoint. Has no effect before the waypoint. This value is added to TECS_LAND_SINK proportional to distance traveled after wp. With an increasing sink rate you can still land in a given distance if you're traveling too fast and cruise passed the land point. A positive value will force the plane to land sooner proportional to distance passed land point. A negative number will tell the plane to slowly climb allowing for a pitched-up stall landing. Recommend 0.2 as initial value.

Automatic Flaperons Configuration

This setup assumes a two-servo, right and left aileron arrangment. In this example I plugged the two servos into two flight controller PWM outputs 1 and 5 for the right and left ailerons respectively.

With the following configuration the ailerons will also function as flaperons (or spoilerons if you reverse them) during the landing.

Configure the transmitter

1. Channel 1 only for ailerons with no other mixing. Note that all mixing will be performed by the flight controller

2. Channel 7 as the flap channel. I used a three-position switch for manual operations.

Configure Flap Parameters

Mission Planner Flap Parameters

Command	Value	Units	Options	Desc
FLAP_IN_CHANNEL	7			An RC input channel to use for flaps control. If this is set to a RC channel number then that channel will be used for manual flaps control. When enabled, the percentage of flaps is taken as the percentage travel from the TRIM value of the channel to the MIN value of the channel. A value above the TRIM values will give inverse flaps (spoilers). This option needs to be enabled in conjunction with a FUNCTION setting on an output channel to one of the flap functions. When a FLAP_IN_CHANNEL is combined with auto-flaps the higher of the two flap percentages is taken. You must also enable a FLAPERON_OUTPUT flaperon mixer setting if using flaperons.
LAND_FLAP_PERCNT	50	Percent	0 100	The amount of flaps (as a percentage) to apply in the landing approach and flare of an automatic landing
SERVO1_FUNCTION	24			
SERVO1_REVERSED	1			
SERVO5_FUNCTION	25			
SERVO5_REVERSED	1			
SERVO7_FUNCTION	3			

After making these settings re-calibrate the transmitter channels in the ArduPlane Initial Setup area. Perform the calibration with the flaps up. Then check to make sure that the ailerons and flaperons move in the correct directions when moving the transmitter sticks.

Also do not forget this crucial test – Make sure that the control surfaces move in the correct directions when under automated control. Do this by switching to AUTO mode and move the airplane to various orientations and watch that the surfaces move to keep the airplane level.

Airspeed Sensor Parameters

I had good results with the Mayan Robotics 4425 airspeed sensor.

mRo 4425 Airspeed Sensor Setup

Command	Value	Units	Options	Desc
ARSPD_PIN	15			The analog pin number that the airspeed sensor is connected to. Set this to 0..9 for the APM2 analog pins. Set to 64 on an APM1 for the dedicated airspeed port on the end of the board. Set to 11 on PX4 for the analog airspeed port. Set to 15 on the Pixhawk for the analog airspeed port. Set to 65 on the PX4 or Pixhawk for an EagleTree or MEAS I2C airspeed sensor.
ARSPD_TUBE_ORDER	1			This parameter allows you to control whether the order in which the tubes are attached to your pitot tube matters. If you set this to 0 then the top connector on the sensor needs to be the dynamic pressure. If set to 1 then the bottom connector needs to be the dynamic pressure. If set to 2 (the default) then the airspeed driver will accept either order. The reason you may wish to specify the order is it will allow your airspeed sensor to detect if the aircraft it receiving excessive pressure on the static port, which would otherwise be seen as a positive airspeed.
ARSPD_TYPE	1			
ARSPD_USE	1		1:Use 0:Don't Use	use airspeed for flight control

Rangefinder Parameters

I used the TFMini LIDAR unit available from Sparkfun. It wired to the Pixracer's second serial port called TELEM2 on the physical unit and configured SERIAL2 in the software:

TFMini Rangefinder Setup

Command	Value	Units	Options	Desc
RNGFND_GNDCLEAR	30	centimeters	0 127	This parameter sets the expected range measurement(in cm) that the range finder should return when the vehicle is on the ground.
RNGFND_LANDING	1		0:Disabled 1:Enabled	This enables the use of a rangefinder for automatic landing. The rangefinder will be used both on the landing approach and for final flare
RNGFND_MAX_CM	600	centimeters		Maximum distance in centimeters that rangefinder can reliably read
RNGFND_MIN_CM	50	centimeters		Minimum distance in centimeters that rangefinder can reliably read
RNGFND_TYPE	8		0:None 1:Analog 2:APM2-MaxbotixI2C 3:APM2-PulsedLightI2C 4:PX4-I2C 5:PX4-PWM 6:BBB-PRU 7:LightWareI2C 8:LightWareSerial 9:Bebop 10:MAVLink	What type of rangefinder device that is connected
SERIAL2_BAUD	115		1:1200 2:2400 4:4800 9:9600 19:19200 38:38400 57:57600 111:111100 115:115200 500:500000 921:921600 1500:1500000	The baud rate of the Telem2 port. The APM2 can support all baudrates up to 115, and also can support 500. The PX4 can support rates of up to 1500. If you setup a rate you cannot support on APM2 and then can't connect to your board you should load a firmware from a different vehicle type. That will reset all your parameters to defaults.
SERIAL2_PROTOCOL	9		-1:None 1:MAVLink1 2:MAVLink2 3:Frsky D 4:Frsky SPort 5:GPS 7:Alexmos Gimbal Serial 8:SToRM32 Gimbal Serial 9:Lidar 10:FrSky SPort Passthrough (OpenTX)	Control what protocol to use on the Telem2 port. Note that the Frsky options require external converter hardware. See the wiki for details.

Concluding Remarks

This was a basic auto landing setup with a flare landing. ArduPlane supports additional landing types like full-stall and reverse thrust that should be interesting and instructional to try.

Fly safely, have fun and learn.