INAV Modes – How they work and how to set up

by, Marc Hoffman
Editing and color commentary by Steve Schlesinger and Marco Lau

Know your modes!

The goal of putting a flight controller in your plane is to allow your planes to do things that weren't possible just a few years ago. Words cannot describe the feeling the first time you flip a switch and your plane comes back to you. What used to be pure science fiction is now a very affordable reality. And this is all just the start of what's to come.

And yet, one criticism of INAV is that it's perhaps too powerful. It's capable of so many things, and yet what you don't know can hurt you. When you installed your flight controller you wanted to use all 16 channels and install all the modes all at once. It certainly easier to do this than to go back over and over again and update INAV. But keep in mind that some of these modes surrender some if not all control of the plane. Thus, you can very realistically watch your plane fly away never to return. With this guide you should be able to figure out what all the modes are capable of doing. It's best to explore them one at a time. There may be certain modes you'll never use, such as camstab. So, be selective in what you wish to include. And no, you don't need to use every switch on your radio to enjoy INAV.

INAV in a fixed wing plane brings a multitude of possibilities. It starts with simple in-flight stabilization which keeps your plane flying like it is on rails. Wind gusts are dealt with in real time and further enhance the flying experience. The ultimate INAV experience are fully autonomous flights, where your plane can fly complete missions over big distances, like a real military drone. It is amazing how far such simple technology in this hobby has been developed but all these features need some knowledge to be able to use correctly.

In this guide, we will explore in detail the different modes and features of INAV and explain how to correctly set them up and how they work. First, we will explain, how every mode works by itself and in the second part, we will explain their dependencies and preconditions.

Part One – Main Flight Modes. <u>The modes in this table cannot be combined with each other:</u>

Mode	Description
STABILIZED (RATE MODE)	This is the default mode of INAV. This is always active if you do not add other flight mode (s). This is similar to the Acro mode on multicopters. INAV will always try to keep the current attitude of the plane if there is no stick input by the pilot. As in most flight modes, the flight controller takes over the complete control of the servos and the input of the pilot controls how fast the plane has to spin around the specific axis (rate control). The speed of the spin is limited by the rate limit in the software on full stick input. (more on that later in the Tuning Guide)
ANGLE	In angle mode, the control will change from rate control to angle control. The plane will always keep itself level if there is no stick input. If there is stick input for roll or pitch, it will change the angle relative to the stick movement. At maximum stick

	movement, the plane will pitch or roll only as far as set in the firmware. There is no automatic control of height and throttle, so the Pilot still needs to be aware of that. The yaw axis is still in a rate controlled mode and only stabilized.
HORIZON	Horizon mode is very similar to Angle mode. The only difference is, that at a certain amount of stick input, Horizon mode will automatically transition to rate control and allows the pilot to do rolls and loops, but the plane goes back to angle control if the stick is below this threshold.
NAV CRUISE	This mode needs a working GPS module. In Cruise mode, the plane will completely autonomously keep its course in the air on a straight path. The pilot does not have direct control over yaw and roll but changes the flight course direction via the roll stick. This means that the roll input will have very limited authority. INAV will do all the needed attitude changes by itself to keep the selected course. Also the throttle is controlled automatically by INAV and is depending on the pitch angle. Cruise throttle needs to be set correctly. This will not apply to the height, the plane is flying at. So, pitch is still controlled in angle mode (2D Cruise). See ALTHOLD mode for 3D Cruise. In summary, in this mode no yaw, limited roll and angled pitch input. Throttle override by pilot is optional.
NAV POSHOLD	With this Mode, you can “park” the plane in the air. It will save the coordinates and height as a center point and try to fly a constant circle around that point. With the yaw stick, the pilot can change the circle direction (if activated). With the pitch stick, the height can be changed. There is no further control possible, while in this mode. POSHOLD needs GPS and barometer to work (without barometer the height will be very unreliable). In summary, in the NAV Poshold, the plane flies in circles. The only two things a pilot can do is change the circle direction and altitude. The Circle size can be configured via CLI.
NAV RTH	Return to home can be one of the most important modes you will ever use. Of course, this needs GPS and Barometer to work. As soon as the pilot ARMs the plane, it will save its GPS position on the Flight Controller. If you ever get in trouble by flying too far away, lose sight or just want to come back from a long-range flight without getting bored staring on the FPV feed, you can enable RTH and the plane will autonomously fly back home. You can control the height of the return with the pitch stick but not the direction. There is also a RTH mode in case of a remote connection loss but this one, behaves slightly different. More on that later.
NAV WP	In WAYPOINT mode it is possible to let the UAV fly nearly complete unattended missions by itself. The pilot can use different applications (INAV Configurator on Windows, MultiWii planner on Linux, INAV Mission Planner on Android, INAV Flight on iOS) to plan waypoints on a map with specific height and upload them to the Flight Controller via USB and also wireless, if you install a Bluetooth or WiFi module. Then you can let the FC automatically fly this mission, as long as you keep in range of your remote. It is not (yet) supported to do missions without control connection. This is an advanced mode, you will want to master the other modes before attempting to work with Nav WP. Your planes should be well trimmed , tuned and calibrated.
MANUAL	The MANUAL control mode is very helpful during the initial tuning phase of the plane. In the case that anything is wrong with your setup, sensor failures, bad PIFF values, unstable flight behavior, you can switch into manual mode, and all automatic stabilization(s) are disabled. The pilot has direct control over the servos and can fly like a normal flight without ANY input from the flight controller. The servo mixing, especially for Flying Wings or V-Tail planes is still done by INAV, so no mixing on the transmitter is necessary. When setting up a new plane the plane

	should be manually trimmed using the Manual mode so that it can fly well without radio trim.

After explaining, what every main flight mode does, we will now look at the additional modes, that cannot be used standalone but can add additional functionalities to the modes above:

Mode	Description
NAV ALTHOLD	Combine with self-level modes: **ANGLE, HORIZON, NAV CRUISE**
	This mode will tell the FC to automatically keep its current height in the air. It will only affect the pitch control type of the plane and only works with self-leveling flight modes. While in plain self-level modes, the pilot controls the pitch angle with the stick input directly (see above). If ALTHOLD is added to one of these modes, it switches in climb-rate control. That means, that the pitch stick will only send commands to change the height at a specific rate and INAV will automatically adjust the needed pitch angle and motor thrust (CRUISE only).
	Values that are relevant: *nav_manual_climb_rate* – value in cm what the maximum climb or descent rate will be on full pitch stick input. If it is set too high, it will be physically limited by nav_fw_climb_angle and airspeed. *nav_fw_climb_angle* – max climb angle used to sustain requested climb rate. Is limited by *max_angle_inclination_pit* (Global max pitch angle). If climb angle is set higher, then max_angle_inclination_pit will be the limit to climb. Be careful setting the climb angle, because too high values can cause a stall and in auto modes, this will likely cause a crash.
AIR MODE	**Should be permanently enabled as a feature to be active on all relevant modes** Combine with: **STABILIZE, ANGLE, HORIZON**
	AIR MODE keeps the PID (PIFF on fixed wing) controller always active, even when throttle is zero. This is very important for all flight modes with manual throttle control. If this mode is disabled, you will loose stabilization if you go to zero throttle and the plane will behave like in **MANUAL** mode but much lower control authority. It is highly recommended to permanently enable this mode as a feature in configuration tab.
	No special values to set up
NAV LAUNCH	Combine with: **STABILIZE, ANGLE, HORIZON, NAV CRUISE, NAV POSHOLD, NAV RTH**
	More information in our Autolaunch manual
SURFACE	**Irrelevant on fixed wing**
TURN ASSIST	**Irrelevant on fixed wing**
HEADING HOLD	**Irrelevant on fixed wing**
HEADFREE	**Irrelevant on fixed wing**
HEADADJ	**Irrelevant on fixed wing**

All the main modes have some settings and variables that can or need to be changed, to fit your needs or fit your plane. This will not include tuning values like PIFF Controller. We will explain these in the tuning guide later. All Modes that are lower in the table will also be affected by the values of the modes above.

Mode	Configuration values	
STABILIZED (RATE)	**Needed Hardware**	Gyro
	roll_rate=20 **pitch_rate=20** **yaw_rate=20** (only with rudder)	Defines the maximum rates (in 10x degrees/s) the plane can turn on the specific axis. The maximum rates need to be determined before in MANUAL mode (See tuning guide). Can be set via GUI in PID-Tuning Tab
	align_gyro=DEFAULT	Sets the correct board alignment. Need to be correct so pitch, roll and yaw movement detected by the sensor, matches the movement of the plane. Can be set via GUI in Configuration tab in 90° steps and flip.
	align_board_roll=0 **align_board_pitch=0** **align_board_yaw=0** (only with rudder	Fine tunes board alignment if it is not precisely mounted in 90° steps. It will change the alignment of the board in 0.1° steps. Positive and negative values possible.
	rate_accel_limit_roll_pitch=0 **rate_accel_limit_yaw=10000**	With these values, it is possible to limit the acceleration of rotation. For small planes this can be very high (or even disabled) but recommended on bigger planes with more than 1 meter wingspan. Limiting the roll, pitch and yaw acceleration can give you a smoother transition between high rotation rates and still flight (hard stick inputs). Do not set it too low. Start with 5000 for pitch on roll and try to figure out best values slowly. If it is too slow, the plane will become extremely sluggish or uncontrollable.
ANGLE	**Needed hardware**	accellerometer
	max_angle_inclination_rll=300 **max_angle_inclination_pit=300**	These values determine the maximum angles in ANGLE flight mode. It also limits the overall angle limit for all other flight modes with auto-level functionality.
HORIZON	**Needed hardware**	accellerometer
	fw_d_level=75	This value sets the transition point, when Horizon mode will switch from angle control to rate control. A value of 75 means, that a roll stick output of more than 75% to each side will cause a full roll movement like in STABILIZED mode.
NAV CRUISE	**Needed hardware**	GPS (baro recommended for ALTHOLD)
	nav_fw_cruise_thr=1400	This is the applied throttle value when in cruise mode. It needs to be high enough to make sure, the plane has enough airspeed to keep a good control authority and does not stall. Rule of thumb: keep the plane at least 30% above stall speed. You can determine the correct throttle in manual flight

		by doing a stall test and take the stall speed as reference.
	nav_fw_allow_manual_thr_increase=OFF	Turning this on, will allow you to override automatic throttle control in all navigation modes. You cannot go below the automatic throttle value (except with motor stop on zero throttle) but you can rise the throttle manually if needed. If this is activated, you should always keep the throttle stick very low, when in auto mode, if you want to have a slow and efficient flight. If throttle is too high, it could rise the turn radius in navigation modes massively.
	nav_fw_min_thr=1200 **nav_fw_max_thr=1700**	These values set the max and min throttle during all navigation modes, when pitch is controlled automatically. These should be set wisely. On planes with good gliding behavior and low drag, the min throttle can be set lower (do not set it to 1000 when using folding props as throttle reactivation can be too quick for a folder). On fast planes like warbirds or light foamboard planes, this should be kept higher, to avoid speed loss. Max throttle is the most important. This must be high enough to keep air speed when the plane is pitching up. It must be high enough to keep airspeed, when INAV is pitching up to *nav_fw_climb_angle.* You should test this manually in ANGLE mode and check with OSD or via LOG. More about this in the Tuning guide.
	nav_fw_bank_angle=20 **nav_fw_climb_angle=20** **nav_fw_dive_angle=15**	These are the angles on pitch and roll axis, that are allowed during all autonomous flight modes. These should be set high enough to get acceptable turn rates and climb or dive speed but not too high. If bank angle is set too high, you risk to loose altitude too quick and due to GPS direction delay, the flight will be very sluggish. Climb angle must not be higher than your motor power allows without getting the plane to stall. And dive angle should also not be too high to make sure INAV has enough time to go level again when diving very low and the plane does not get too fast.
	nav_fw_pitch2thr=10	This value determines how much throttle INAV will add or subtract from *nav_fw_cruise_thr* for every degree of pitch. Example for default values: In level flight the ESC gets 1400 throttle value. When pitching up 15 degrees, INAV will give a throttle value of 1550. With pitch down 20 degrees, it will send 1200 to the ESC. Upper and lower values are limited by min and max throttle (see above). Should be tested in ANGLE mode and should be set to a value, where airspeed keeps the same at every climb and dive angle.

	nav_fw_cruise_yaw_rate=20	This is the turning rate when applying full roll stick input. Don't be confused by the yaw. This also applies to Wings and V-Tails. On wings INAV will use bank and yank to change its course but it will also use rudder if available. This should be set higher on smaller planes. The maximum yaw rate depends on the max allowed nav bank angle.
NAV POSHOLD	**Needed hardware**	GPS (baro recommended for ALTHOLD)
	nav_fw_loiter_radius=5000	This sets the redius of the loiter circle if the plane is in POSHOLD or RTH LOITER. Default is 5000cm (50m) but should be set higher on bigger planes.
	fw_loiter_direction=RIGHT	This value determines if the final loiter direction will be clockwise (RIGHT) or counter clockwise (LEFT). It is also possible to select the loiter direction manual with the YAW stick. To enable this, set the value to YAW
NAV RTH	**We will do a separate Document for RTH and Failsafe settings.**	
NAV WP	**nav_wp_radius=100**	Determines the distance to a set waypoint, to accept it as reached. This must be set higher for FW because it is very unlikely, to hit a waypoint at 100cm precision. 1000-3000cm are good values here, depending how agile your plane is and how far you set the WP apart.
	nav_wp_safe_distance	This is the maximum distance between the Home-Position and the first waypoint. This is a safety value, that avoids accidental flyaway, in case a wrong mission is loaded for a location far away.
MANUAL	**manual_rc_expo** **manual rc_yaw_expo**	This value will add an expo for RC inputs in MANUAL mode. You should disable any expo setting in your transmitter and only use INAV setting here.
	manual_pitch_rate **manual_roll_rate** **manual_yaw_rate**	With these values you can limit the maximum servo throw in manual mode.