Grab a cup of coffee (or a beer); and let's go through the V3 Flight Prep Checklist. It presents a good overview of not only setting things up; but all of the various inputs the system is using to provide AOA and OWS cues. It also provides some insight into the physics behind the calculations.

When you download the system software from our GitHub site, you'll find three folders: OnSpeedTeensy, OnSpeedWiFi, and Libraries. OnSpeedTeensy is the primary system software, OnSpeedWiFi is the firmware for the WiFi interface and Libraries are sub-routines that the CPU (best thought of as ancillary programs: filters, etc.).

Let's take a closer, step-by-step look at Version 1.7 of the checklist:

The first portion describes how to get into the core software on my Mac. At the heart of the system is the basic Arduino code that runs on the Teensy CPU in the V3 box. The Teensy is a small, powerful computer that has a 32 gig SD card for data storage and excellent MIDI capability. MIDI is normally used for music, but because our system is primarily aural, the quality of various tones is important, and having good "musical" capability (the ability to adjust the audio waveform) is important. The primary system software is OnSpeedTeensy. Currently, the only setting we adjust in the primary code is the ASYMMETRIC_GYRO_LIMIT (around line 50) as we experiment with various roll and yaw rates for asymmetric over-G warning. This is "rolling G" warning. Eventually, these settings will be fixed and there won't be a need for normal users to adjust it. There is a note that reminds you to RELOAD the software any time you make a change. You load the software by plugging into the V3 box using a micro USB cord. It is not possible to upload system software wirelessly. The first time you load WiFi code, you must do so using a cable. Software and Firmware versions are contained in the Arduino files and also displayed on the top of the WiFi home page.

After the software is loaded via cable, you can disconnect the computer and power the V3 box with any portable back-up battery source that has a USB connection. This will allow you to go to a comfortable chair with your laptop to continue the configuration process. Use your WiFi controls on your computer or iPhone to connect to the ONSPEED network (password: angleofattack). Once you've established a network connection, open your web browser and type onspeed.local in the address line (or 192.168.0.1 on Windows). The system home page will open.

<u>Click on SETTINGS and then AOA CONFIGURATION.</u>

The first value is AOA smoothing. This is best thought of as a gain control. Small numbers mean a more responsive AOA tone, albeit with larger perturbations. Larger numbers mean smoother operation, but more lag with gust loads or high G onset rates. We put this up front so folks can easily access this setting for experimentation. While we experiment with automating this, ***<u>we found a baseline setting of about 20 gives good all-around performance</u>***.

The next value is PRESSURE smoothing. This is the smoothing algorithm applied to the differential pressure sensors. There are two highly accurate sensors that measure pitot (P_{FWD}) and AOA (P_{45}) pressures. ***Set pressure smoothing to 15.***

The next field is the data source. ***Set this to SENSORS.*** This means that the system is using the data from the on-board sensors (pressure and inertial measurement unit) to generate the tone and optional energy display outputs. The other options in this field are TEST POTENTIOMETER, which uses your volume potentiometer to simulate different angles of attack and play the proper tone patterns. The RANGE SWEEP option plays the basic tone pattern through the headset, and REPLAY LOG FILE plays recorded data real time. These three settings are designed for test work; but the range sweep can be used to familiarize new users with the tone pattern on the ground, if desired.

The next box is FLAP CURVE 1. The flap curves are the heart of the AOA measurement system, and it's important to understand that there are three components to each of these "curves." The first is obvious: what position are the flaps in? Accurate AOA calculations depend on any AOA system knowing what position the flaps are in. ***Position the flaps, fill in the first field (flap angle) and hit READ.*** The flap position sensor reading will be recorded.

The next parameters are actual, absolute angle of attack parameters for the various tone "set points." ***We will use the "USE ACTUAL AOA" button to set these points in flight.*** The set points are where the various tones start, so the L/D_{MAX} AOA is where the fast tone begins and is coincident with L/D_{MAX} in a flaps up configuration. Since ONSPEED is an AOA band about ± 1 degree, it has a top ("fast") and bottom ("slow") set point. Note that a combination of the AOA SMOOTHING setting and the size of the ONSPEED band provide overall damping performance and are fully adjustable. OnSpeed Fast AOA is where the tone transitions from fast 400 Hz beeps to the solid ONSPEED tone. OnSpeed Slow AOA is were the tone shifts from the solid ONSPEED tone, the high-pitched 1600 Hz "slow tone" beeps, and Stall Warning AOA is where stall warning occurs. L/D_{MAX} occurs at the CAS for best glide, ONSPEED is approximately 1.3 x V_S and stall warning is generally desired at V_S + 5. ***In flight, establish these conditions, allow airspeed and power to stabilize, trim and hit USE ACTUAL AOA. The system with gather a couple seconds of data an insert a measured AOA in the field.***

The next box has three options: Polynomial, logarithmic, and Exponential. This is math stuff and the heart of what we call a "hard tune" calibration. It describes the type of equation we used to "curve fit" the AOA data when we plot absolute AOA (in degrees) against pressures. These data are derived from flight test, and once the formula is determined, it doesn't change. Our primary objective is to automate this portion of the process and make it transparent to the user.

The software is currently set up to allow 5 different flap settings, which should be sufficient to cover most situations. One other physics nugget: it may be possible to combine curves. When we flight test and plot data, if those data are close at multiple flap settings, a single curve or two may accurately capture those data with sufficient accuracy to reduce the total number of curves required for an airplane. For example, an RV-3/4/6/7 or 8 can collapse all of the data into a single curve. The type of flap fitted, and airfoil shape will determine whether or not this is practical. Plain flaps have less impact on curve fit than slotted flaps. You'll fill in as many boxes as required to accommodate normal flap configuration. For example, in the RV-4 test bed, there are three flap settings: Flaps 0, flaps 20 and flaps 40. The Sling LSA uses four curves: Flaps 0, flaps 10, flaps 20 and flaps 40.

The next field is for the calibrated test boom. ***Select DISABLED.*** Note: The calibration curves for the boom are on the card and were determined by the manufacturer. We subsequently apply installation and upwash correction to boom alpha data during analysis. The boom is only used for flight test work and is not part of a normal installation.

The next two selections are important. They describe the orientation of the box and are critical for proper sensor calibration. The box should be installed relatively parallel to the longitudinal axis and as close to the lateral axis as practical (i.e., roughly on the aircraft centerline). First, ***select the orientation of the pressure ports*** (these are the three 1/4" pressure quick release fittings), then ***select the orientation of the top of the box***.

Enable serial EFIS data for airplanes equipped with electronic flight information systems used for flight test. This allows EFIS data to be recorded with pressure data for post-flight analysis (if desired). For daily use (i.e., non-test operations) recording EFIS data is optional. For airplanes without EFIS, select disabled. Select EFIS type.

Next, ***enable potentiometer volume control. Adjust the volume control to the low position and press READ. Then, adjust volume control to the high position and press READ.*** After system set-up is complete, we'll use the audio test to confirm proper stereo operation for airplanes equipped with a stereo ICS.

Select an IAS to activate the system during takeoff and mute it during landing. This is a personal preference. If optimum performance is desired during takeoff, this value should be set to 25-30 to allow the pilot to listen to the acceleration so the option exists to smoothly rotate and capture ONSPEED for initial climb segment (if desired). The ONSPEED cue provides best angle of climb performance. The L/D_{MAX} cue provides best rate of climb performance.

Enable 3D audio if the airplane is equipped with a stereo ICS. This feature allows the pilot to "listen to the ball." If the the slip/skid ball slides to the left, so does the tone and vice versa. The pilot "steps on the tone" to center it up. ***If the airplane has a monoaural intercom, set 3D audio to disabled***, otherwise the tone will gain down when the slip/skid ball is displaced to one side (depending on which channel is used for ICS, left or right).

Enable or disable SD card logging, as desired. This is primarily for troubleshooting and flight test work. It is recommended that logging be initially enabled until the system is fully programmed and normal operation is verified. A new log file is created any time power is applied and/or a system boot occurs. Files are numbered from 1 (oldest) to X (highest number

= newest) and are downloaded via WiFi or cable post-flight, if desired. A format command may be sent by Wifi to reformat the card. The log also contains a copy of the default configuration file.

<u>Enable or disable Over-G audio warning, as desired and select the appropriate category, or use the G-limit test setting for flight test, familiarization or training.</u> This setting has an artificially low maximum G setting that allows you to experiment with the warning in a low-G condition. This can be used to demonstrate the effect of asymmetric maneuvering in a training environment (i.e., the reduction in allowable G loading with "rolling and pulling" simultaneously).

<u>Set Serial Out Format to Garmin G3X regardless of whether or not an EFIS is fitted or what type it is. Set Serial Out Port to NONE.</u>

<u>Select SAVE</u> to save configuration settings. Failure to hit save and exiting from the AOA CONFIGURATION tab will result in default to previous settings.

The next step in the set-up process is to measure sensor bias. *The airplane should be in a hangar and undisturbed for this step, the pressure sensors and accelerometers are highly sensitive.* If the airplane cannot be indoors, conditions should be calm as any aircraft movement will affect biases. You should not be in or on the aircraft. Use the WiFi interface to perform this function. From the onspeed.local home page, Select SETTINGS > SENSOR CONFIGURATION.

Measure the angle of the fuselage reference line (FRL) in degrees using an accurate, electronic level. The fuselage reference line is used for weight and balance calculations and will be found in maintenance weight and balance instructions (i.e., how to the weigh the airplane). It may also be found in the builder's instructions for experimental types. For example, some Cessna aircraft use a horizontal fuselage seam ahead of the horizontal stab as a reference and RV's use the canopy rail/fuselage longeron. ***<u>Insert the measured angle of the FRL in the white field and hit CALIBRATE.</u>*** Calibration takes a few moments. If the page appears to lock up, hit the "refresh page" function. You will receive a message when sensor calibration is complete, and biases will be displayed on screen.

Next select TOOLS > LOG FILES. Click once on OnSpeedConfig file. It will download. Open it with a text editor, and select COPY ALL. Navigate to your Arduino folder and open OnSpeedTeensy. Click on the arrow on the right side of the tab bar. This will open a menu. Click on DEFAULT CONFIG. This will open a tab in Arduino with the default settings. Highlight the current lines from <CONFIG> through <CONFIG> and select PASTE to overwrite old settings. Now, plug the computer into the V3 box with a cable and upload OnSpeedTeensy again.

Disconnect the computer and reconnect the battery. The system will reboot with correct configuration and sensor bias settings. Select SETTINGS > SENSOR CONFIGURATION and record bias settings on the checklist, if desired. There are three categories of bias: pressure (for the pressure sensors), IMU (for the gryoscopes) and boresite for pitch computations. “Boresite” is where the nose of the airplane is pointed, and we want pitch to read zero when it’s aligned with the FRL. This is required for an automated AOA calibration. After calibration, the pitch bias is the angular difference between the box and the FRL/boresite. Measured pitch is what the accelerometers see, and corrected pitch is what the pilot sees when he looks at the horizon (or artificial horizon). Corrected pitch should be equal to the FRL measurement, plus or minus a 1/10th of a degree.

<u>Adjusting Set Points in Flight After Initial Programming (IOS Only)</u>

1. Calculate set points as described previously.
2. Turn off DATA on iPhone
3. Connect WiFi to ONSPEED network
4. Open browser to onspeed.local
5. SETTINGS > AOA CONFIGURATION
    a. Establish desired condition, stabilize
    b. Press USE LIVE AOA
        i. Process takes 2 seconds
    c. Scroll to bottom of page and SAVE
    d. Verify proper set point operation
        i. Accelerate and decelerate through set point, compare to desired CAS

Note: after intial set points are SAVED, it is necessary to land, and refresh the default configuration file in OnSpeedTeensy, as described above.

<u>Restoring Default Settings</u>

This is the “fat finger” recovery mode. It only works, however, if the default config file in Arduino OnSpeedTeensy is up to date with correct settings!

1. Connect WiFi to ONSPEED network
2. Open browser to onspeed.local
3. SETTINGS > AOA CONFIGURATION
4. Scroll to bottom of page and select RESTORE DEFAULT

<u>LED Not Breathing</u>

1. RESET 1 AMP Circuit Breaker to hard boot system