

# ArduPilot Conference 2022

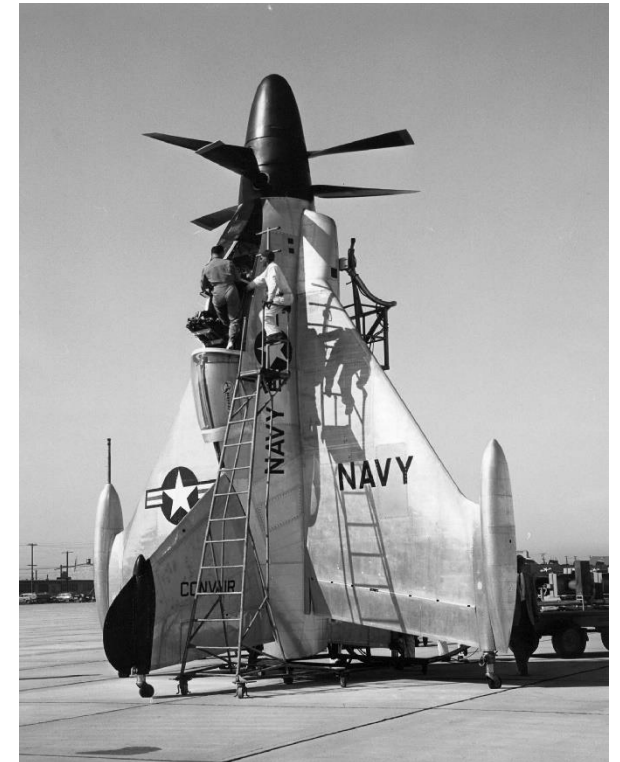
## Tailsitter update

Peter Hall

# What is a tailsitter?

A VTOL plane that hovers at a different attitude to that it uses in forward flight.

Convair XFY Pogo – experimental tailsitter 1954



# Types



Dual motor - Marco Robustini's Explora



Vectored dual motor- FT Bronco



Single motor – Tridge's  
Addiction X



Copter - SwanK1 – off the shelf AP compatible



Copter – Pierre Losa's Jetwing

# Contents

- Smaller changes
- Control surface gain scailing
- Min outflow speed
- Control surface less
- Transitions
- Weathervaning



<https://youtu.be/5W3f13zCWsM>

# Smaller changes

- **Q\_TAILSIT\_ENABLE** – [#18015](#)
  - Hides params for none tailsitter users
  - Removes odd combinations of **Q\_FRAME\_CLASS** and **Q\_TAILSIT\_MOTMX** to enable tailsitter
- Set level in both reference frames - [#18311](#)
  - FW mode calibrate roll and pitch
  - VTOL mode calibrate pitch and yaw
- Transition to and from inverted FW flight - [#17118](#)
- Dedicated build for SwanK1 - [#18254](#)
- EKF3 nose up init issue fixed - [#15351](#)
  - No more YAW inconsistent warnings

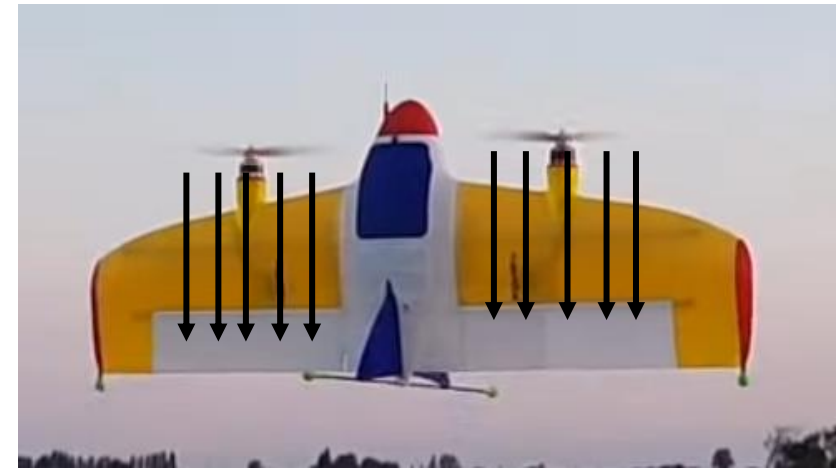
# Control surface gain scailing

Primarily used on dual motor none vectored. Control surfaces are only method for actuation of pitch and yaw.

Response is dictated by airflow over the control surfaces, this depends on thrust and forward speed.

New option estimates the airspeed seen by control surfaces.

**Q\_TAILSIT\_GSCMSK = 4** and **Q\_TAILSIT\_DSKLD > 0**



Marco Robustini's Explora

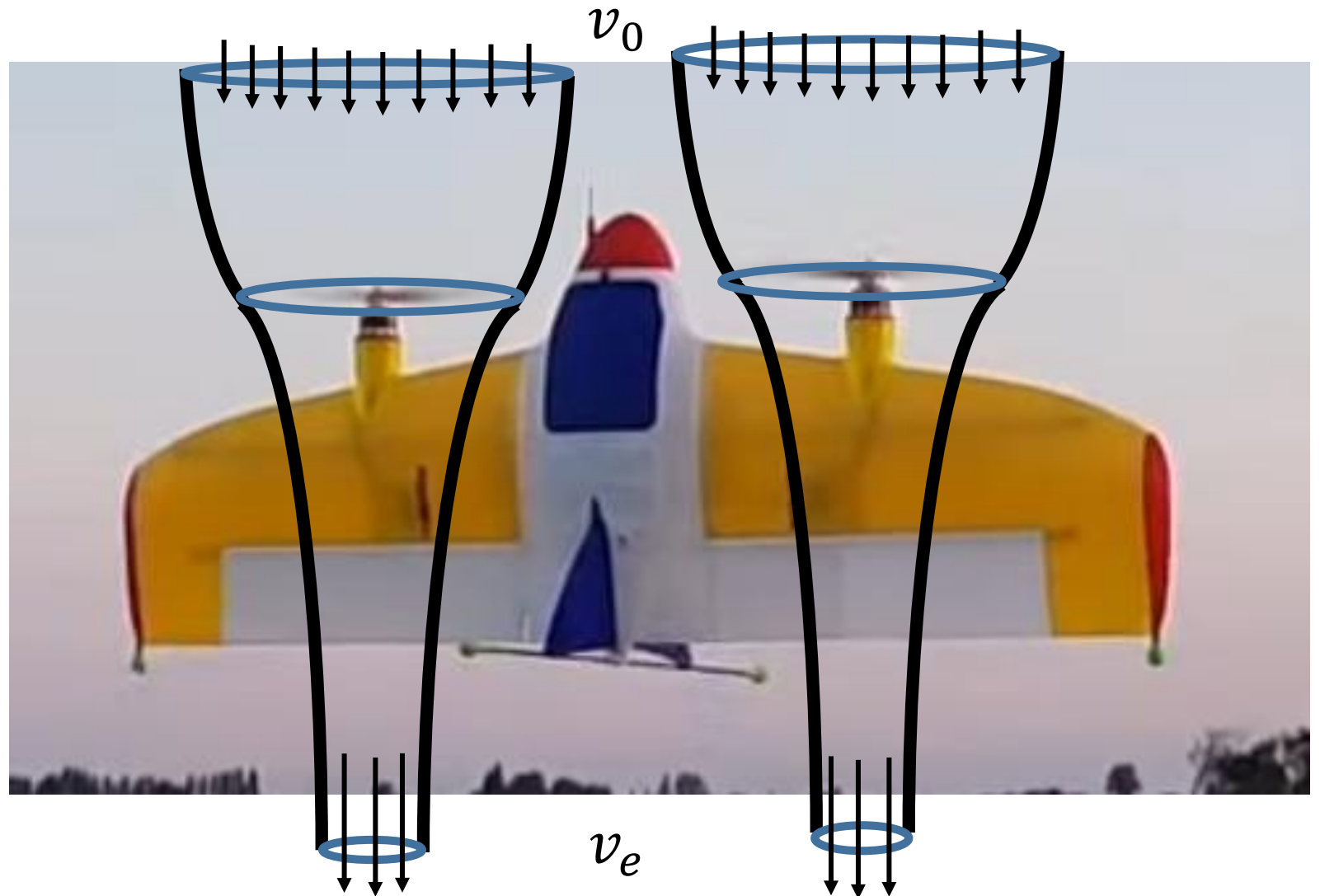
# Actuator disk theory - [# 15719](#)

Conservation of mass over control volume.

Instantaneous pressure change over disk.

Derived from Bernoulli's equation.

$$T = \rho A_{disk} \frac{v_e^2 - v_0^2}{2}$$



# Actuator disk theory - [# 15719](#)

$$1. \quad T = \rho A_{disk} \frac{v_e^2 - v_0^2}{2}$$

$$2. \quad v_e^2 = \frac{2T}{\rho A_{disk}} + v_0^2$$

$$3. \quad T = \frac{t}{t_{hover}} mg$$

$$4. \quad v_e^2 = \frac{\frac{t}{t_{hover}} 2mg}{\rho A_{disk}} + v_0^2$$

$$5. \quad v_e^2 = \frac{m}{A_{disk}} \frac{\frac{t}{t_{hover}} 2g}{\rho} + v_0^2$$

$$6. \quad \text{Disk loading} = \frac{m}{A_{disk}}$$

Disk loading, set with **Q\_TAILSIT\_DSKLD**.  
Vehicle mass divided by total disk area of propellers.



# Actuator disk theory - [# 15719](#)

Normalise by hover to give scaling of 1 in hover case, does not mess up PIDs

$$\text{Hover case: } \frac{t}{t_{\text{hover}}} = 1, v_0 = 0$$

General case:  $v_0$  = airspeed, from sensor or EKF

$$\text{Control surface gain: } \frac{v_{e \text{ hover}}^2}{v_e^2} = \frac{\frac{m \cdot 2g}{A_{\text{disk}} \rho}}{\frac{m}{A_{\text{disk}}} \frac{t}{t_{\text{hover}}} \frac{2g}{\rho} + v_0^2}$$

Scaling constrained between **Q\_TAILSIT\_GSCMIN** and **Q\_TAILSIT\_GSCMAX**

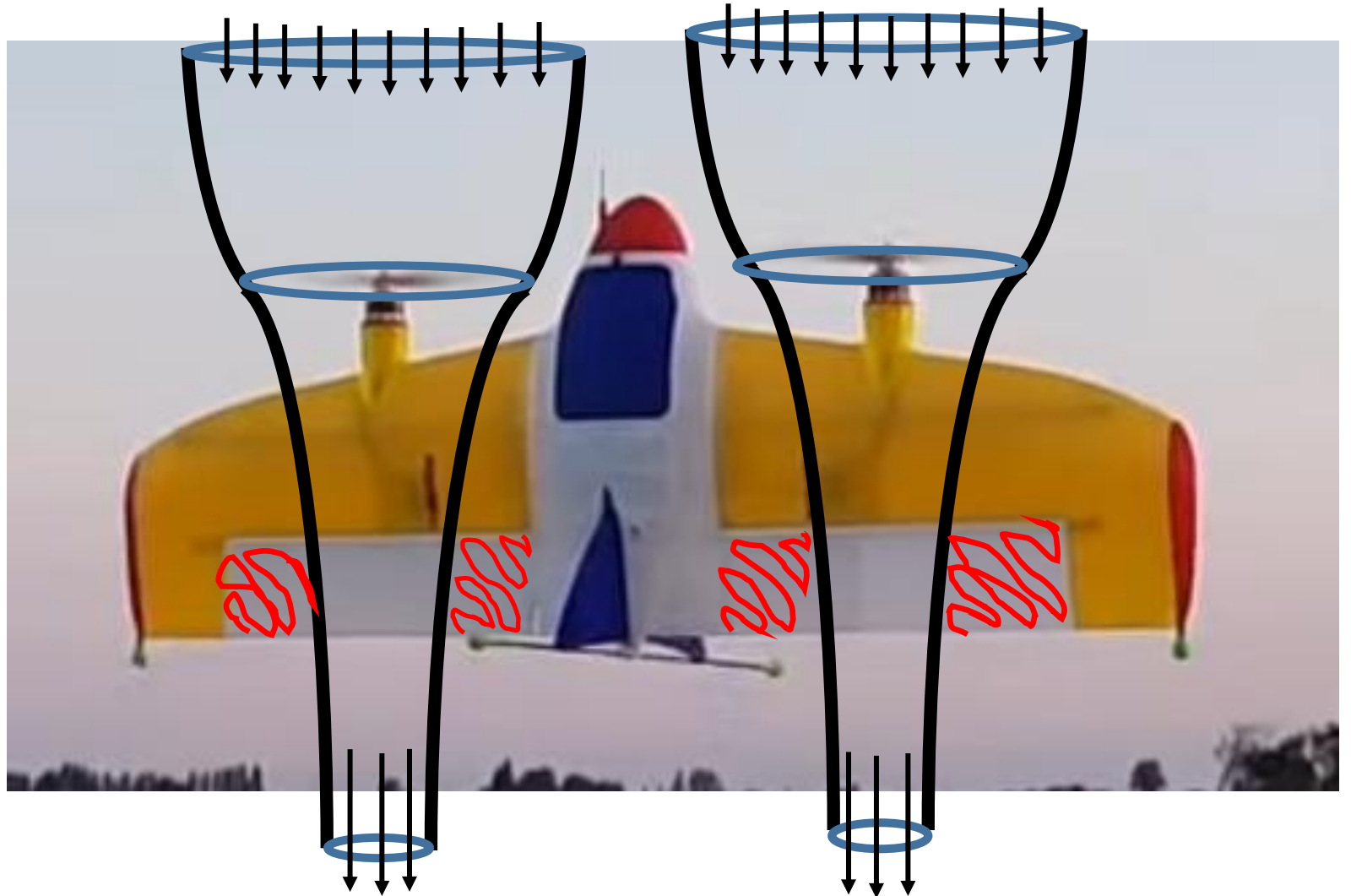
# Actuator disk theory - [# 15719](#)

Control volume does not cover all of the control surface.

To compensate a lower value of  $Q_{TAILSIT\_DSKLD}$  is used to represent the average airflow over the control surface. Half area gives half  $Q_{TAILSIT\_DSKLD}$ .

Tune by using high throttle to gain airspeed and reducing to low throttle and coasting. This covers a range of throttles and airspeeds.

Lower  $Q_{TAILSIT\_DSKLD}$  if oscillations at high throttle.

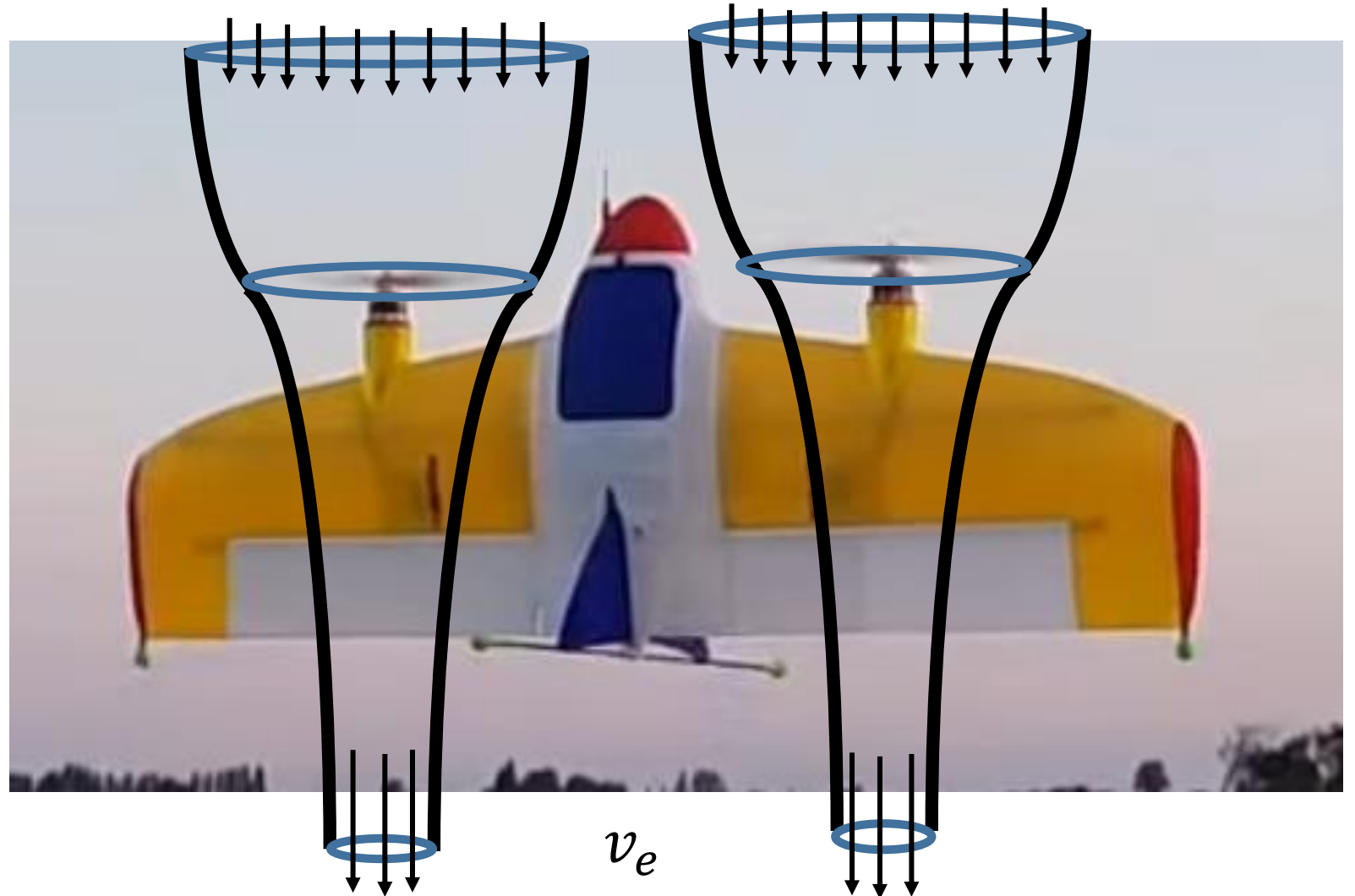


# Min outflow speed - [#19249](#)

## Q\_TAILSIT\_MIN\_VO

Requires disk theory gain scaling to be setup.

Increases throttle to always give minimum airflow over control surfaces.



# Min outflow speed - [#19249](#)

1. 
$$T = \rho A_{disk} \frac{v_e^2 - v_0^2}{2}$$

2. 
$$T = \frac{t}{t_{hover}} mg$$

3. 
$$t = \frac{\rho A_{disk} \frac{v_e^2 - v_0^2}{2}}{mg} t_{hover}$$

4. 
$$v_e = Q\_TAILSIT\_MIN\_VO$$

Climb case,  $v_0 =$  airspeed

$$t = \frac{\rho A_{disk} \frac{v_e^2 - v_0^2}{2}}{mg} t_{hover}$$

Climb case,  $v_0 =$  body frame X velocity

$$t = \frac{\rho A_{disk} \frac{v_e^2 + v_0^2}{2}}{mg} t_{hover}$$

# Min outflow speed - [#19249](#)

Results in low minimum throttle limit with forward airspeed, higher minimum throttle with no or negative airspeed.

**Q\_TAILSIT\_MIN\_VO** too high will result in flyaway.

Need to tune, not all of control surface in stream tube. Increase until minimum throttle does not lose control when descending.

Maximum throttle limit constrained to value derived from **Q\_A\_THR\_MIX\_MIN**, **Q\_A\_THR\_MIX\_MAX** and **Q\_A\_THR\_MIX\_MAN**. High values result in larger possible increase in throttle.

# Control surface less - [#19249](#)

Bad idea - With airspeed prop effectiveness decreases and aerodynamic forces increase. Fly too fast -> crash!

**Q\_TAILSIT\_ENABLE = 2**

Enables active stabilization in forward flight.



Forces “air-mode” - stabilization active at zero throttle in forward flight.

See **Q\_A\_THR\_MIX\_\*** params again.

## Control surfaces with motors - [#14453](#), [#19463](#)

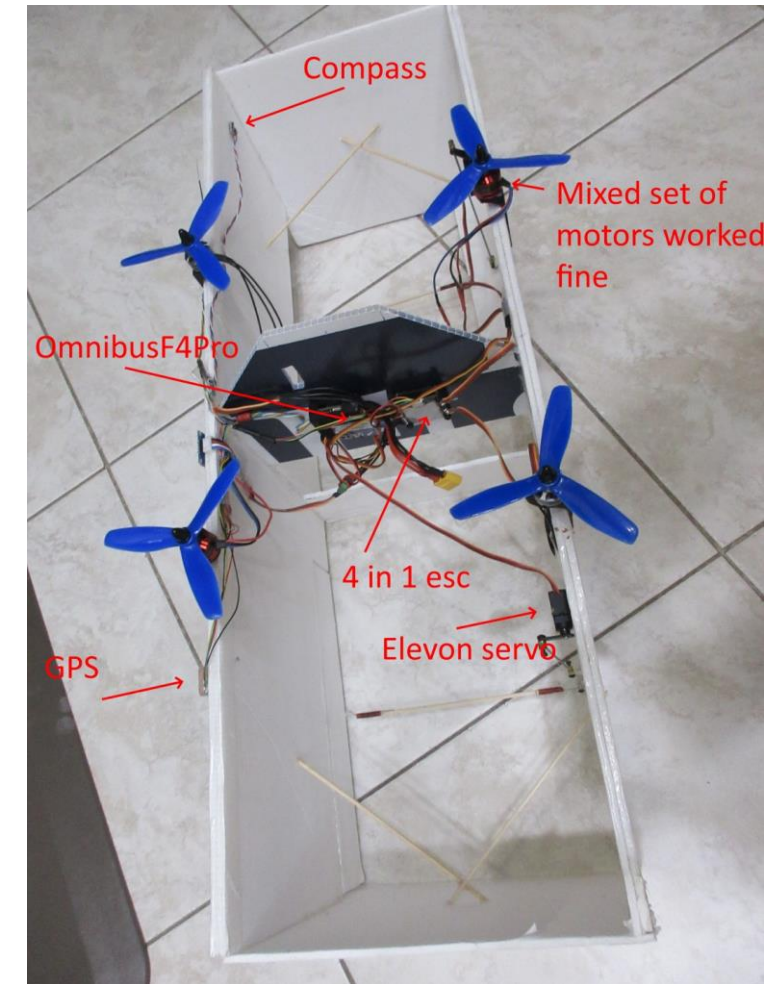
Much better, no problems at high speed.

**Q\_TAILSIT\_VT\_R\_P**, **Q\_TAILSIT\_VT\_P\_P** and **Q\_TAILSIT\_VT\_Y\_P** scale control surfaces relative to motors.

**Q\_ASSIST\_SPEED** to enable and disable motors based on airspeed in forward flight.

**Q\_OPTIONS: 8** – Motors only q assist - use plane control surface outputs and I terms.

**Q\_TAILSIT\_MOTMX:** to select active motors in FW, 15 here



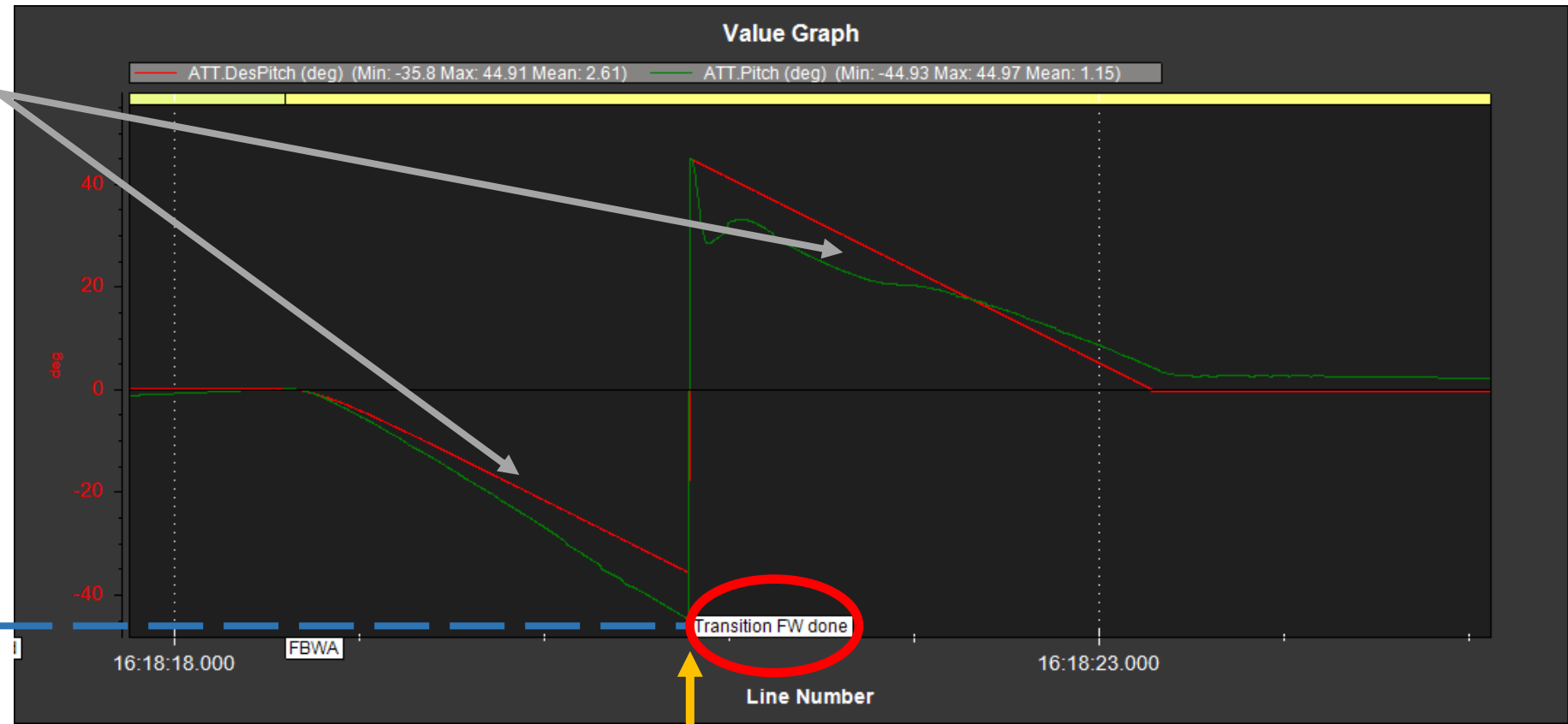
Copter – Henry Wurzburg's Box Kite

# Transitions – to Forward flight

Too many improvements to mention! Must have good VTOL and FW tune first.

**Q\_TAILSIT\_RAT\_FW**

**Q\_TAILSIT\_ANGLE**



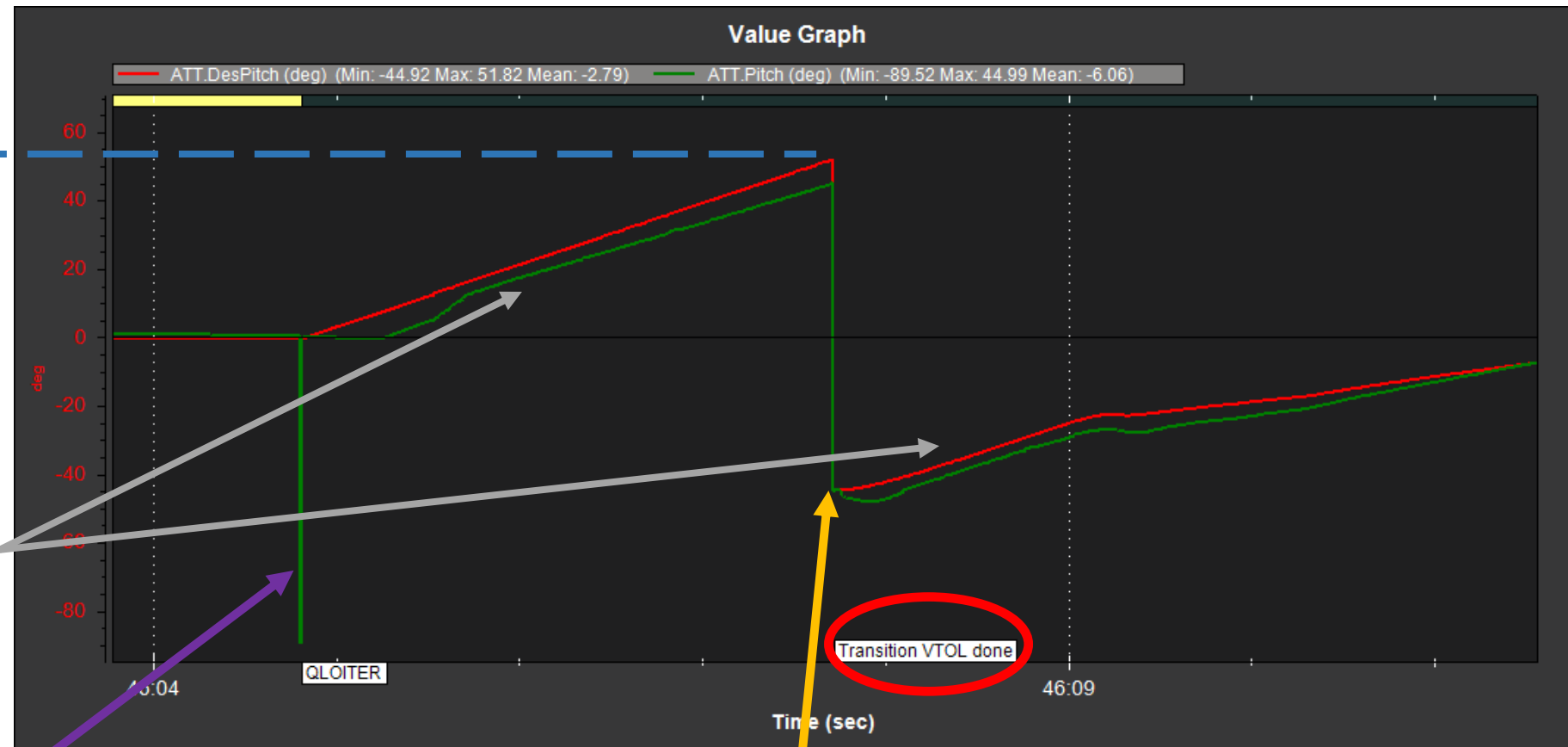
Controller hand over from VTOL to FW



# Transitions – to VTOL flight

Q\_TAILSIT\_ANGLE\_VT

Q\_TAILSIT\_RATE\_VT



Logging race condition

Controller hand over from FW to VTOL

# Transitions – to VTOL flight

Q\_TAILSIT\_MIN\_VO

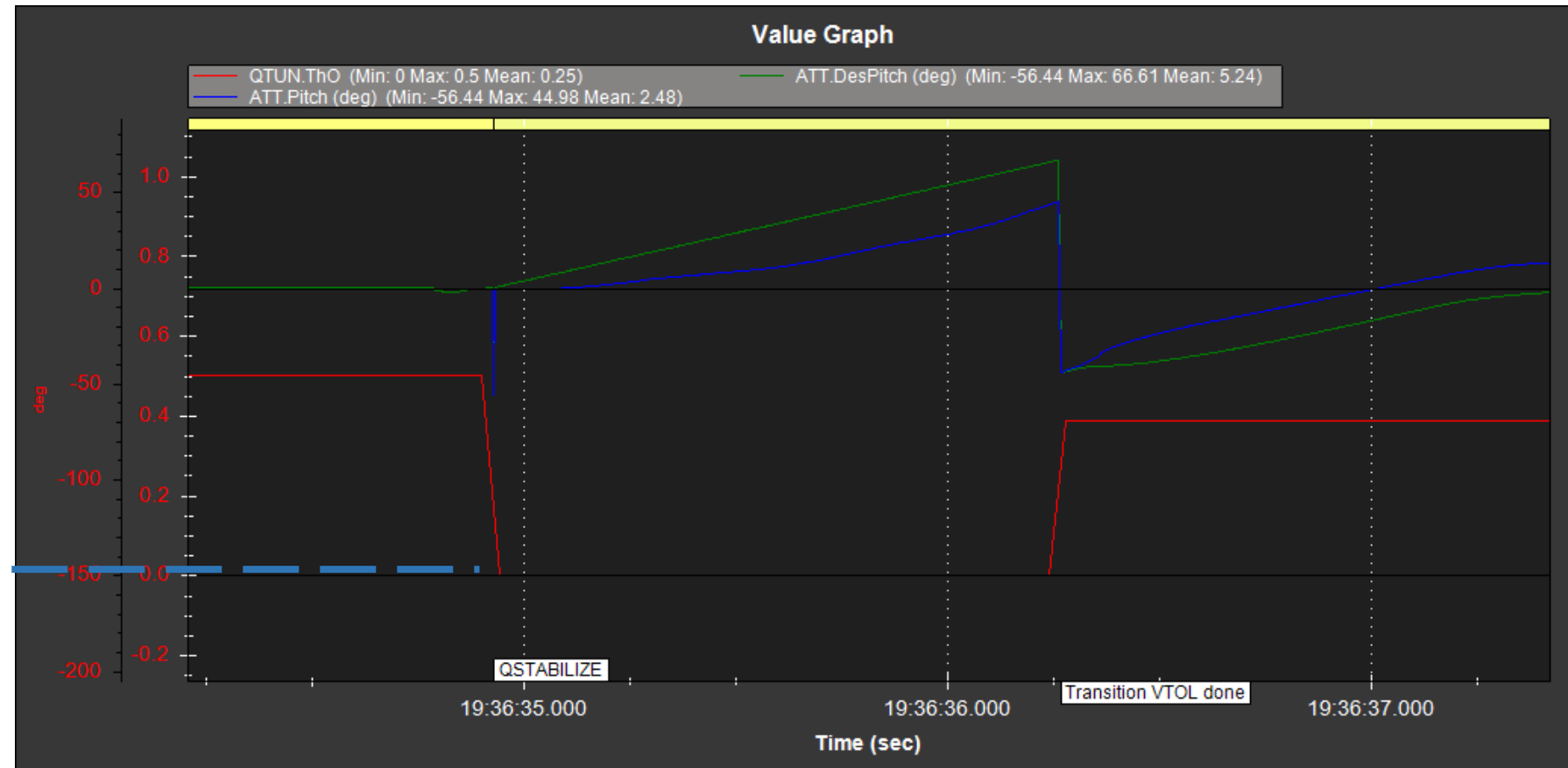
Q\_A\_THR\_MIX\_MIN

Q\_A\_THR\_MIX\_MAX

Q\_A\_THR\_MIX\_MAN

To bump throttle to min level.

Q\_TAILSIT\_THR\_VT



# Weathervaning - [#19859](#)

**Q\_WVANE\_ENABLE**  
**Q\_WVANE\_TAKEOFF**  
**Q\_WVANE\_LAND**

Nose into wind,  
Nose or tail into  
wind,  
Side into wind,  
tail into wind

**Q\_WVANE\_GAIN**



# Questions?

Marco Robustini's Explora  
<https://youtu.be/hy-UXrUSplU>



# Questions?

Tridge's SwanK1

<https://youtu.be/iRpVvW-AAyA>



# Questions?

<https://youtu.be/ktcWGpBBqEQ>

