We would like to thank the reviewers and editor for the generally positive feedback and constructive comments. The suggestions have been implemented in this revised manuscript, and we believe it is ready for publication. In the resubmission, new and revised text are shown in blue.

Please find below our response to comments that require revisions or further explanations.

## RESPONSE TO REVIEWER 1

**The paper would be strengthened by including additional robustness studies, such as the effects of sensor noise, time delays, actuator saturation, wind-direction changes, different turbulence realizations, and lower airspeed conditions.**

We have added most of the suggested analyses in the revision:

- Figures 16 and 17 includes 50 deg/s actuator rate limit, 20 Hz discrete controller, and 0.1 sec feedback delay. In Fig. 14, the wind speed changes direction by 30 deg during reel out but the target cylinder is not adjusted. In Fig. 15, we realign the target cylinder with the new wind direction mid-reel-out. Both cases show the controller successfully keeps the kite on track.

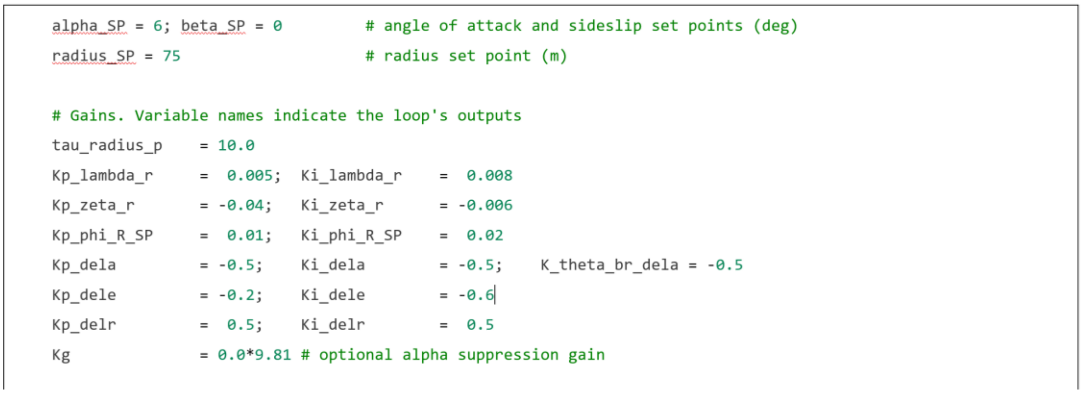
- Lower airspeed conditions are now discussed in the text concerning Fig. 22 on page 23. When flying in lower airspeeds, the winch speed must be reduced accordingly to keep airspeed above stall. Fig. 22 shows the kite flying stable circular orbit in 8 m/s wind.

- Different turbulence realisations will be covered by a future publication that extends the same flight control system to take advantage of turbulence eddies for additional power.

- We have considered adding sensor noise to the revision. However, doing so requires further discussion on its implementation that extends the already-long paper even further. The wind speed plots in Figs. 19a and 20a show non-smooth readings caused by turbulence, which affects the $\alpha$ and $\beta$ readings in Figs. 19b and 20b. Although this isn't sensor noise per se, we hope the closed-loop responses provide some indications of our controller's ability to handle noisy readings (which are always post-processed with some form of filtering in practice).

**The authors mention that the controller gains were tuned empirically and follow time-scale separation principles. However, the actual gain values are mostly embedded within the block diagrams. A dedicated table summarizing all controller gains would improve clarity, reproducibility, and ease of implementation for future researchers.**

This is a good point. To further facilitate implementation by future researchers, we now include the full code for the controller in appendix C. The code allows implementation on the user's chosen open-loop AWES simulator. We refer to this code at the end of the abstract and in the final paragraph of section 3.2. Within the code, a section listing all the controller gains is included, shown below:



```
alpha_SP = 6; beta_SP = 0          # angle of attack and sideslip set points (deg)
radius_SP = 75                     # radius set point (m)

# Gains. Variable names indicate the loop's outputs
tau_radius_p    = 10.0
Kp_lambda_r     =  0.005;  Ki_lambda_r    =  0.008
Kp_zeta_r       = -0.04;   Ki_zeta_r      = -0.006
Kp_phi_R_SP     =  0.01;   Ki_phi_R_SP    =  0.02
Kp_dela         = -0.5;    Ki_dela        = -0.5;    K_theta_br_dela = -0.5
Kp_dele         = -0.2;    Ki_dele        = -0.6
Kp_delr         =  0.5;    Ki_delr        =  0.5
Kg              = 0.0*9.81 # optional alpha suppression gain
```

**It would also be helpful to provide additional implementation details, including:**

- **actuator deflection and rate limits (for example, flap deflection limits for the KM1 model),**
- **simulation sample time and solver settings,**
- **and whether the KM1 simulation model has been validated against real flight-test data.**

Actuators are modelled as first-order lags with a time constant of 1/50 sec and rate-limited to 50 deg/s. We've added this information to Table 1 and on line 112. All analysis shown in the paper did not encounter rate or deflection saturation. The most challenging case is Fig. 16, in which a max rate of 15 deg/s is reached by the rudder (line 360). The paper also now makes the distinction between demanded and actual control surface deflections (e.g., $\delta_{a_{SP}}$ vs $\delta_a$), although the two signals are near-identical in all cases presented. We also commented on how better performance can be achieved by using conventional flight control design techniques (lines 215-221).

Simulation sample time and solver settings are now discussed in a new section numbered 4.3. We have also discovered that using 15 tether nodes is excessive, and reducing to 8 nodes provides significantly improved performance (see Table III and lines 430-437).

Yes, the simulator has been validated against flight-test data. One case is provided in Fig. 3 and discussed on lines 142-148.

**The paper applies a largely unified cascaded control architecture, where most operating conditions are handled through changes in set points, outer-loop logic, or small controller extensions rather than switching between fundamentally different controllers. While this simplicity is one of the strengths of the work, it may also be beneficial to discuss whether different flight phases of the AWES operation (such as launch, reel-out, reel-in, transition, and landing) would eventually require phase-dependent cascaded control strategies beyond the current inner- and outer-loop structure.**

Indeed, different control architectures are required for other flight phases. We have noted this distinction in our revision (lines 82-85), indicating that our cascaded approach is intended for the reel out phase only. We also refer readers to research on AWES control during other phases.

**Finally, there appears to be a typo in the equation reference on page 6, where the text should refer to Eq. (12).**

Fixed.

## RESPONSE TO REVIEWER 2

**l 36 : "Equilibrium solutions exist only when gravity is ignored and the circular trajectory is perpendicular to the wind" don't (static) equilibria also exist higher in the wind window, with the kite pointing to the north of the sphere? Please be more precise.**

Agreed. This is an oversight on our side. We have changed the statement to 'Equilibrium responses during circular flights' (line 36).

**l 57 : "However, they require specialist knowledge to implement" this is not an argument to disqualify control laws from the literature. It may simply mean that they require more work to ease the practical implementation. But it is an argument to compare your proposed solution to the literature.**

Thank you for your comment. We have changed this statement to:

'However, they may require more effort to design and implement than classical controllers do.'

We have also revised the first sentence of the subsequent paragraph to better present our controller's role in the AWES literature (lines 62-64):

'Accordingly, a reel-out flight control law resembling classical designs with continuous guidance provides a familiar working space for practitioners, which can be useful during the early simulator development phase, where the model may undergo multiple revisions and requires repeated retuning.'

**l 133 : what the reference plane is and how it is defined is unclear throughout most of the paper. Please clarify how it is defined and what is its relation to the kite's periodic trajectories or transient behaviour. This is the main issue with the paper, and this core concept should be clarified.**

We agree that the reference plane and its contribution to the feedback law need to be described better. The first part of section 3.1 has been rewritten, providing a step-by-step guide to construct the reference plane. After the new Fig. 5, a new paragraph on lines 184-193 is provided to describe how periodic trajectories can be defined by the reference plane.

**l 139, 146 and Fig 3b [now Fig 4b] : it is unclear if $Z_R$ should align with the earth's up or down vector when $\lambda_R$ = $\zeta_R$ = 0.**

We agree that the original figure was unclear. When $\lambda_R$ = $\zeta_R$ = 0, $Z_R$ points in the negative $X$ direction, and $X_R$ points in the negative $Z$ direction. We've revised the new Fig. 4b to indicate the positive directions of the two angles $\lambda_R$ and $\zeta_R$. In addition, a new Fig. 5 is provided to illustrate the $\lambda_R$ = $\zeta_R$ = 0 case, removing ambiguity.

**Fig 3 [now Fig. 4]. Adding the kite may (?) help to clarify the impact of the reference plane's orientation**

Agreed. The new Fig. 5 now fulfils this remit.

**The control inputs are the control surface angles. How is their saturation taken into account? Are anti-windup methods implemented, and how does the kite behave during saturation?**

Actuators were modelled as first-order lag, although they were not mentioned in the initial submission. This has been remedied (see the updated table 1). All results show that the required control surface movements had low rates and small deflection magnitudes (around 5 deg max). However, as both reviewers have noted the need for accounting for rate saturations, we have presented additional analyses surrounding Figs. 16 and 17, which include the following:

- 50 deg/s actuator rate saturation
- 0.1 sec feedback delay
- Discrete controller with a 20 Hz sample rate
- Sudden change in wind direction.

Despite the above, the highest deflection rate recorded is only 14 deg/s in the rudder (mentioned on line 360), suggesting that rate saturation is a small risk. Deflection saturation is also deemed not a risk, although instability can occur if excessive deflection is commanded, usually from attempting to fly below the cut-in wind speed or during temporal drops in wind speed. In these instances, anti-windup should be used to prevent unstable responses.

**l 162 : "implies that the reference plane's orientation [λR, ζR] is known"? This seems like an assumption, but isn't it always true in practice? If so why phrase it this way?**

Agreed. What we wanted to say was that the values for $\lambda_R$ and $\zeta_R$ should be provided, either by the user or by the outer loop as shown in section 3.2. We have revised this statement to 'This roll control method requires knowledge of the reference plane's orientation $\lambda_R$ and $\zeta_R$. In this section, we treat these two angles as user inputs, and section 3.2 will explain how $\lambda_R$ and $\zeta_R$ can be controlled automatically by the outer loop.' (line 207-209).

**l 179 : "circle centre overlapping the winch when viewed from the wind-facing direction" ⇒ "circle center on the ground"**

Fixed (see line 230-231).

**Fig 8 [now Fig 11] & l 249 : $X_P$ are drawn as vectors, but the considered as "coordinates". Pleas correct. l 249 do you mean instead the elevation angle of point P? (same for $Y_P$ ).**

Apologies for the confusion. $X_P$, $Y_P$, and $Z_P$ are axes of the production plane, which define the target cylinder. Therefore, the vector $[X_P, Y_P, Z_P]$ denotes the kite's location relative to the production plane. To avoid confusion, we have rewritten the first paragraph in section 3.2 to explain how the production plane is constructed and the notations used. This includes the new example provided, quoted below:

“Fig. **Error! Reference source not found.** depicts the production plane originating from point $P$ with Earth-axis coordinates [$P_X$, $P_Y$, $P_Z$] = [200, 0, –150] m. If the kite is also located at point $P$, then the kite’s location is [$X$, $Y$, $Z$] = [200, 0, –150] m using Earth-axis coordinates, and [$X_P$, $Y_P$, $Z_P$] = [0, 0, 0] m on the production plane.”

Regarding line 249 in the initial submission, we have revised the text below the new Fig. 11 to explain the process better. Point P and the production cylinder are fixed during reel out. What changes are the reference plane’s orientation angles $\lambda_R$ and $\zeta_R$. Part of the confusion could be caused by the term ‘reference’ appearing in both ‘reference cylinder’ and ‘reference plane’, which are not related. In the revision, we have changed ‘reference cylinder’ to ‘target cylinder’.

**l 267 : how is the climb angle defined and tracked? (explain more than ”via λP ”)**

We have expanded this description, found at the beginning of section 4.1:
“A typical reel-out trajectory is presented in Fig. 13, which tracks a target cylinder of 50-75 m radius (75 m in this case), originating from point $P$ with Earth-axis coordinate [$P_X$, $P_Y$, $P_Z$] = [200, 0, –150] m, tilted up by 13°, and pointing in the downwind direction ([$\lambda_P$, $\zeta_P$] = [13°, 0°]). Setting $\lambda_P$ to 13° results in a slight climbing trajectory that reduces the risk of the tether scraping the ground at long tether length but at the cost of higher cosine losses (Diehl, 2013). In practice, this loss can be mitigated by stronger winds experienced at higher altitudes.”

- **l 275 : what is “control travel saturation”?**

We were referring to maximum deflection. The wording has been changed to ‘control surfaces magnitude saturation’ to avoid confusion.

- **l 281 : “both $\zeta_P$ and $\lambda_R$ are 0” ⇒ ”both $\zeta_P$ and $\lambda_P$ are 0”**

Fixed.

- **Fig 13 [now fig Fig 18]: what is the color gradient? turbulence? what is the unit?**

We forgot to include a description – apologies. The colour shows changes in wind speed over time based on LIDAR data. This figure has been updated.

- **l 307 : “the turbulence box is convected downstream with the mean wind speed” please clarify**

We’ve added additional descriptions on lines 389-391, reproduced below:

This modelling approach follows Taylor's frozen turbulence hypothesis, which states that the turbulent eddies move downstream with the mean wind speed and assumes the structures remain mostly unchanged as they propagate (Taylor, 1937).

- **Please clarify if the control gains are kept identical throughout the paper**

Yes, control gains are kept identical, except for cases where the $\alpha$ suppression element is activated. We have added a note on lines 310-311.

- **l 365 : has noted**

Fixed.

- **l 378 : "The kite with highest altitude experiences more control difficulty, but notably produces 46% less power" "The kite with highest altitude experiences more control difficulty, and notably produces 46% less power"**

Fixed.

- **l 383 : how does it compare using the realistic wind profile from Fig 13?**

In the revision, Fig. 20 uses the wind profile in Fig. 18b and generates 101 kW. In a realistic wind profile, flying higher will benefit from stronger wind at the expense of cosine losses, creating a complex relationship and requiring an optimisation study to determine the ideal reel-out height. We will investigate this topic further in a future publication.

- **l 470 : "Appendix C presents the stability proof of the controller" ⇒ "Appendix C presents the stability proof of the α dynamics in closed-loop with the proposed controller"**

Fixed

- **l 489 : it is preferable to stick to a realistic scenario (i.e. the two ground stations are separated)**

Agreed. We've re-run the multi-kite analysis using two winches with 100 m of lateral separation.

- **l 511 : "this method does not provide full navigation capabilities as seen in circular-flight analysis" what is limited if one follows F8 trajectories? Please be more specific**

Changed to: "this method cannot provide non-symmetric flight capabilities as seen in circular-flight analysis (i.e., sideway and diagonal reel out)" (lines 639-640).

**Also, a recap of all the (state-space) equations that should be implemented on the onboard computer would be appreciated to ease the further control implementation.**

To help readers implement the controller, we now include the full code for the controller in appendix C. The code is written as a system of 7 first-order ordinary differential equations.

## ADDITIONAL CHANGES

The time-history plots in figures such as Fig. 13 have been reorganised from a 2x3 to a 3x2 grid to make them more legible in double-column format.

All three control law extensions have been merged into a single section (Section 6).

We found that our reel-out controller contains elements of virtual holonomic constraints, which is a nonlinear control method to track a limit cycle. The literature review has been expanded to reflect this relationship (lines 68-78).

Figure 2 has been updated with the correct data. The previous version used the wrong sign for flaps, resulted in lower-than-expected lift coefficients.