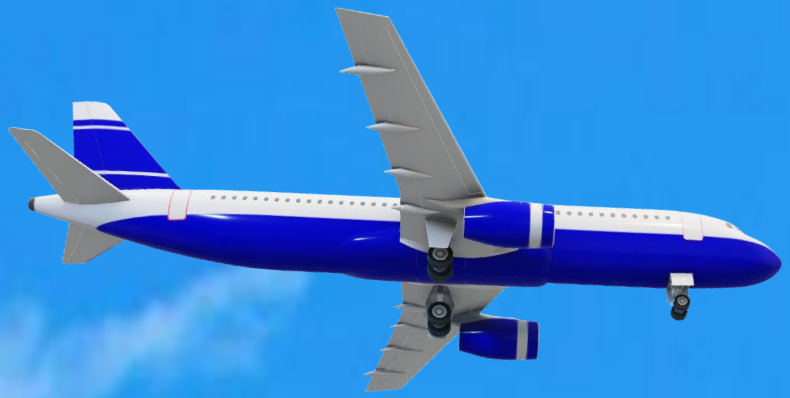
Aircraft conflict resolution



Introduction

Our problem concerns resolving air conflicts, with the objective of avoiding collisions between aircrafts while keeping them out of danger zones. To address this problem, a hybrid control system combining discrete and continuous control elements was implemented.

Control input event

$\sigma = 1$

$Init = \{q_1 \times (x_r^2 + y_r^2 \geq 25)$

Cruise

q_1

$\tau := 0$

$$\begin{pmatrix} x_r \\ y_r \end{pmatrix} := R\left(\frac{\pi}{2}\right)\begin{pmatrix} x_r \\ y_r \end{pmatrix}$$

Half-circle

$\tau \leq \pi/\omega$

q_2

$\tau := \pi/\omega$

$$\begin{pmatrix} x_r \\ y_r \end{pmatrix} := R\left(\frac{\pi}{2}\right)\begin{pmatrix} x_r \\ y_r \end{pmatrix}$$

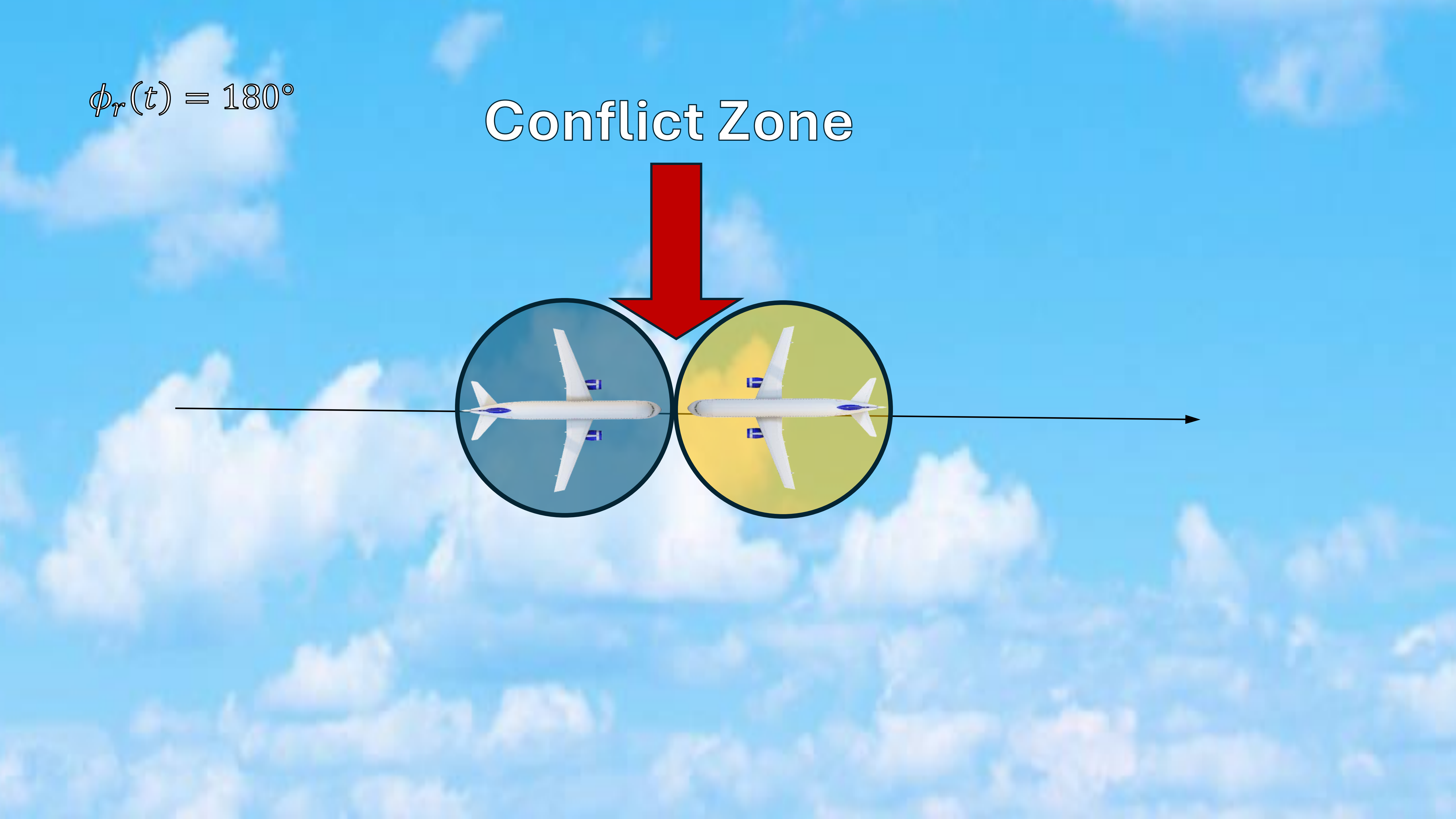
Cruise

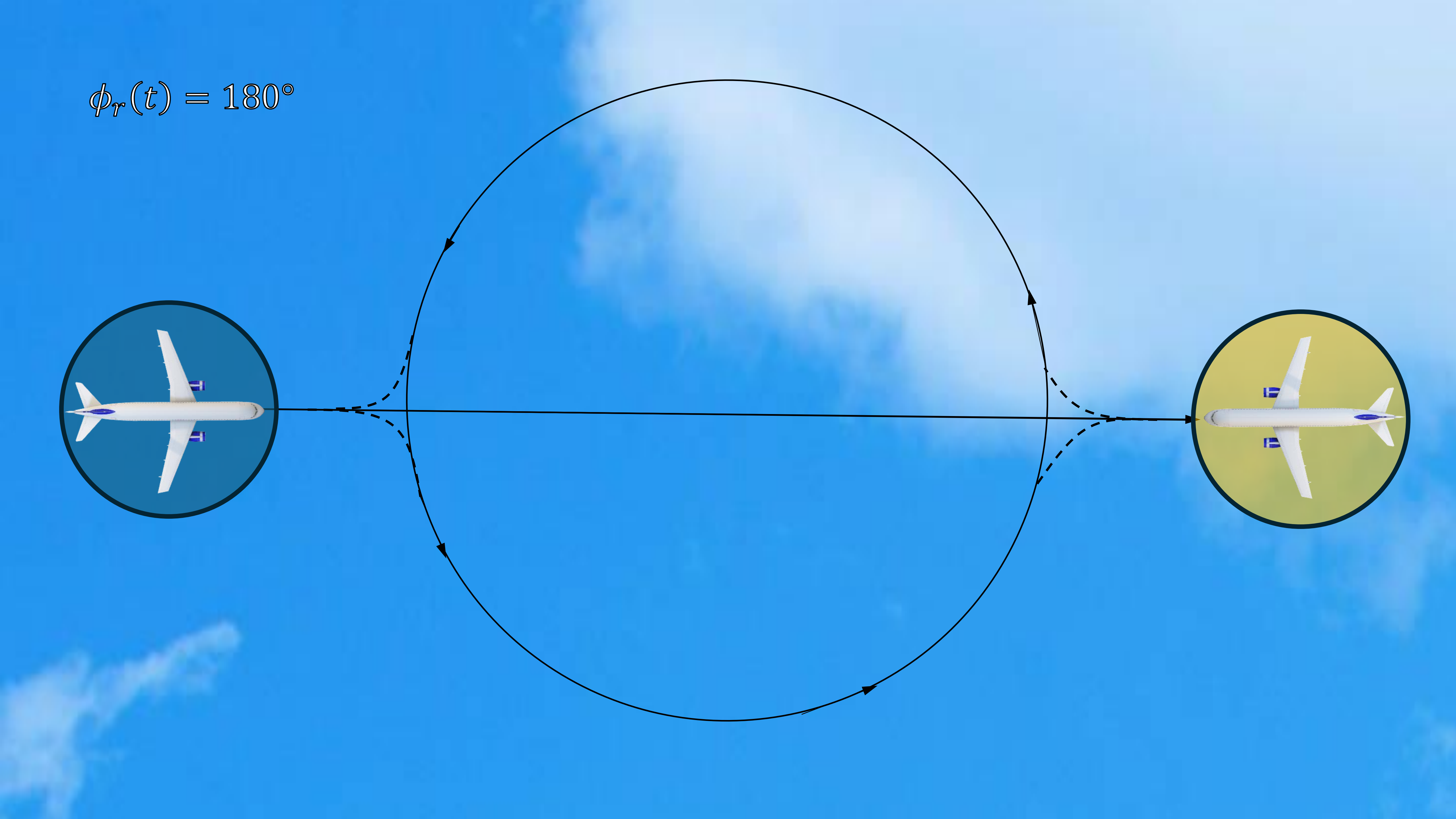
q_3

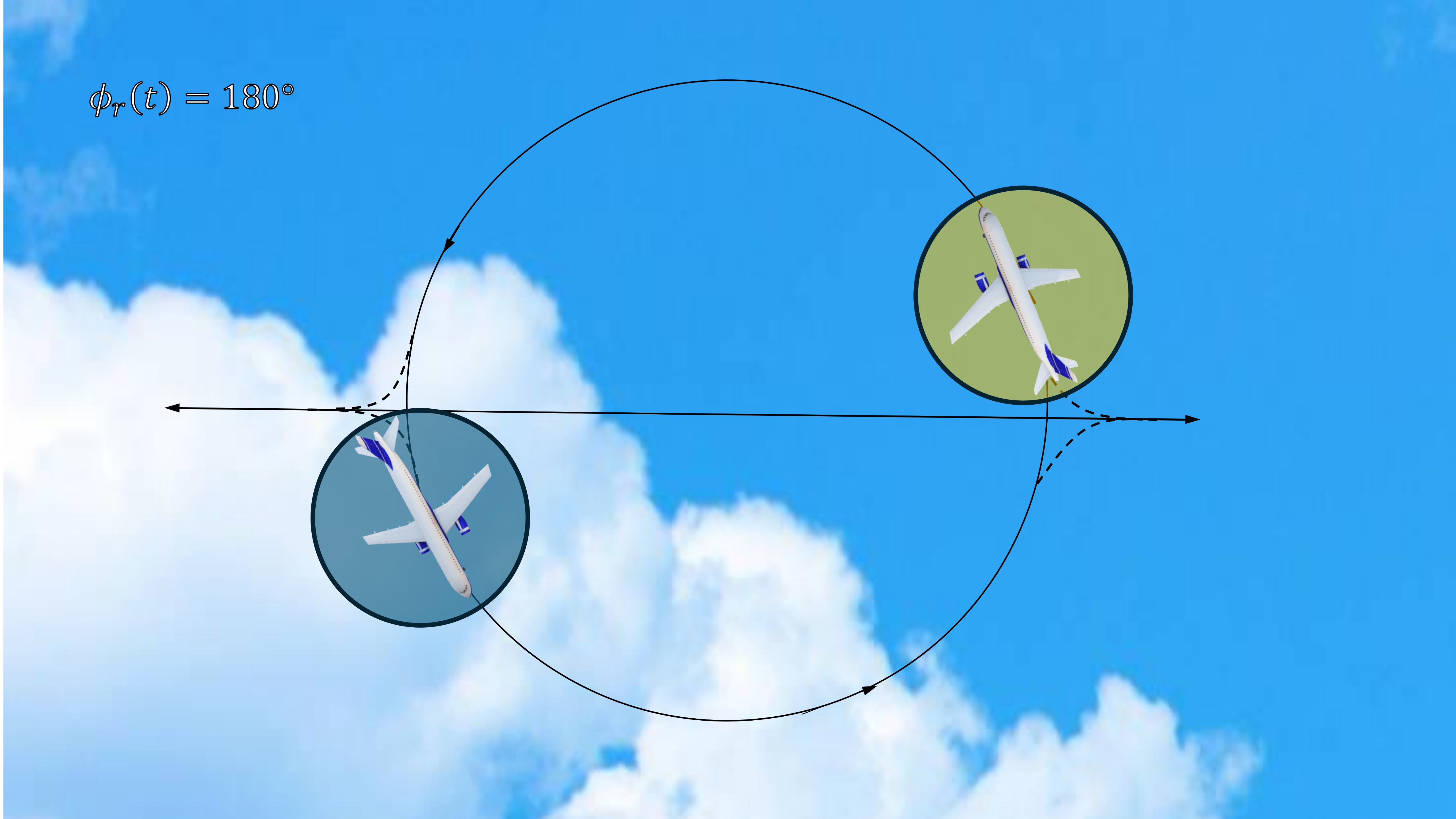
$$\begin{aligned} \dot{x}_r(t) &= -v + v \cdot \cos[\phi_r(0)] \\ \dot{y}_r(t) &= v \cdot \sin[\phi_r(0)] \\ \dot{\phi}_r(t) &= 0 \end{aligned}$$

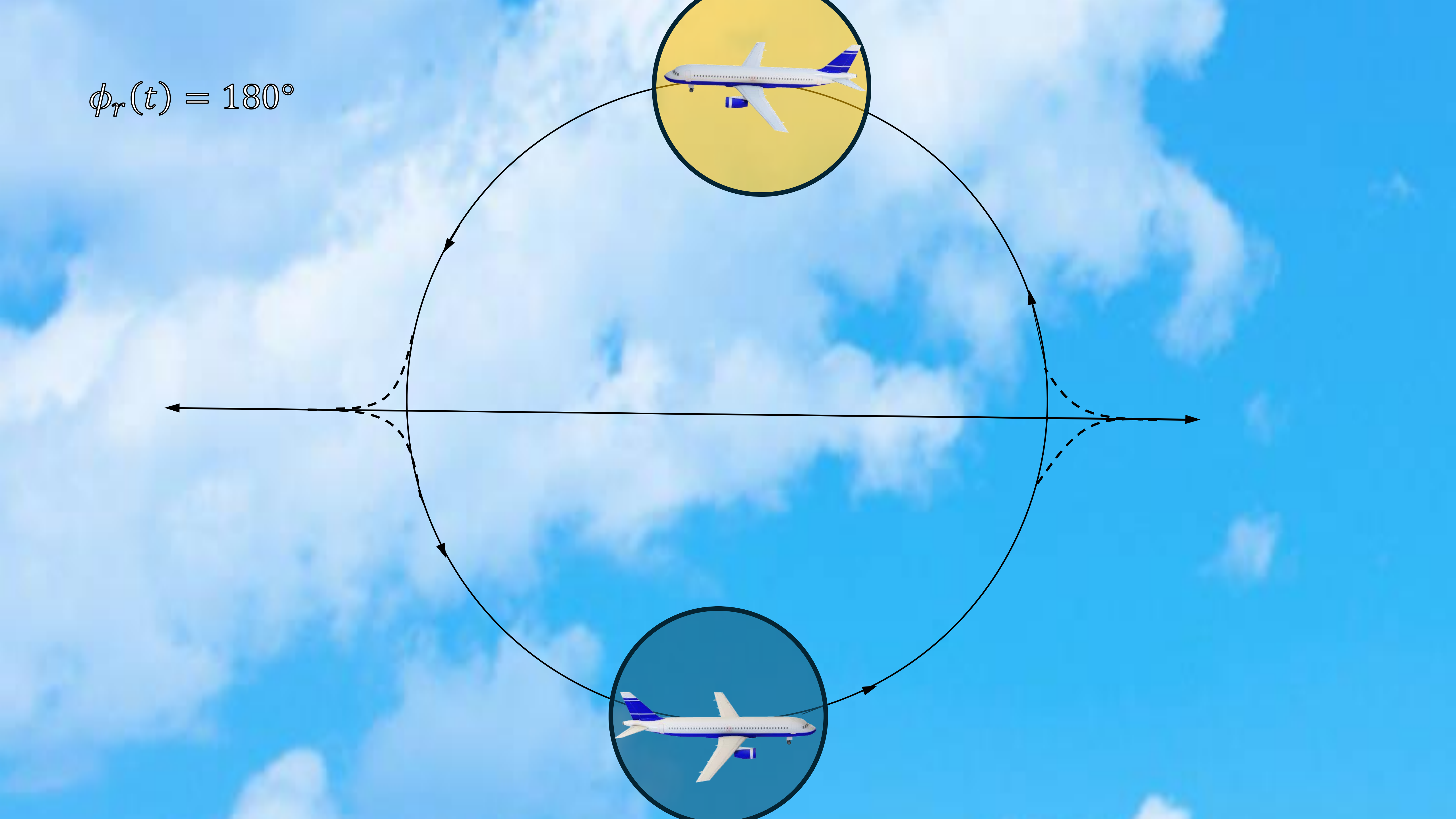
$$\begin{aligned} \dot{x}_r(t) &= -v + v \cdot \cos[\phi_r(0)] + \omega y_r(t) \\ \dot{y}_r(t) &= v \cdot \sin[\phi_r(0)] - \omega x_r(t) \\ \dot{\phi}_r(t) &= 0 \\ \dot{\tau}(t) &= 1 \end{aligned}$$

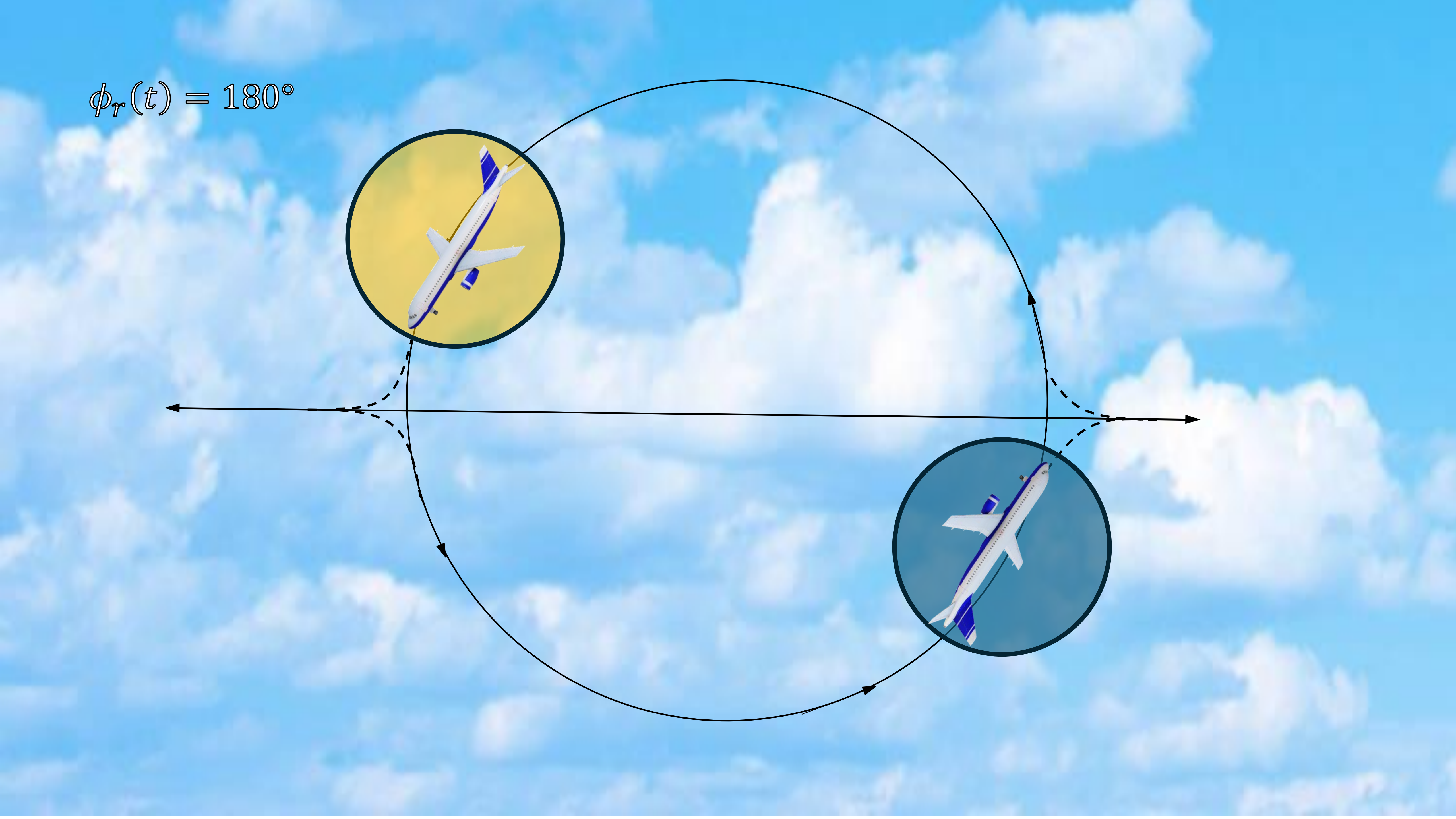
$$\phi_r(t) = 180^\circ$$

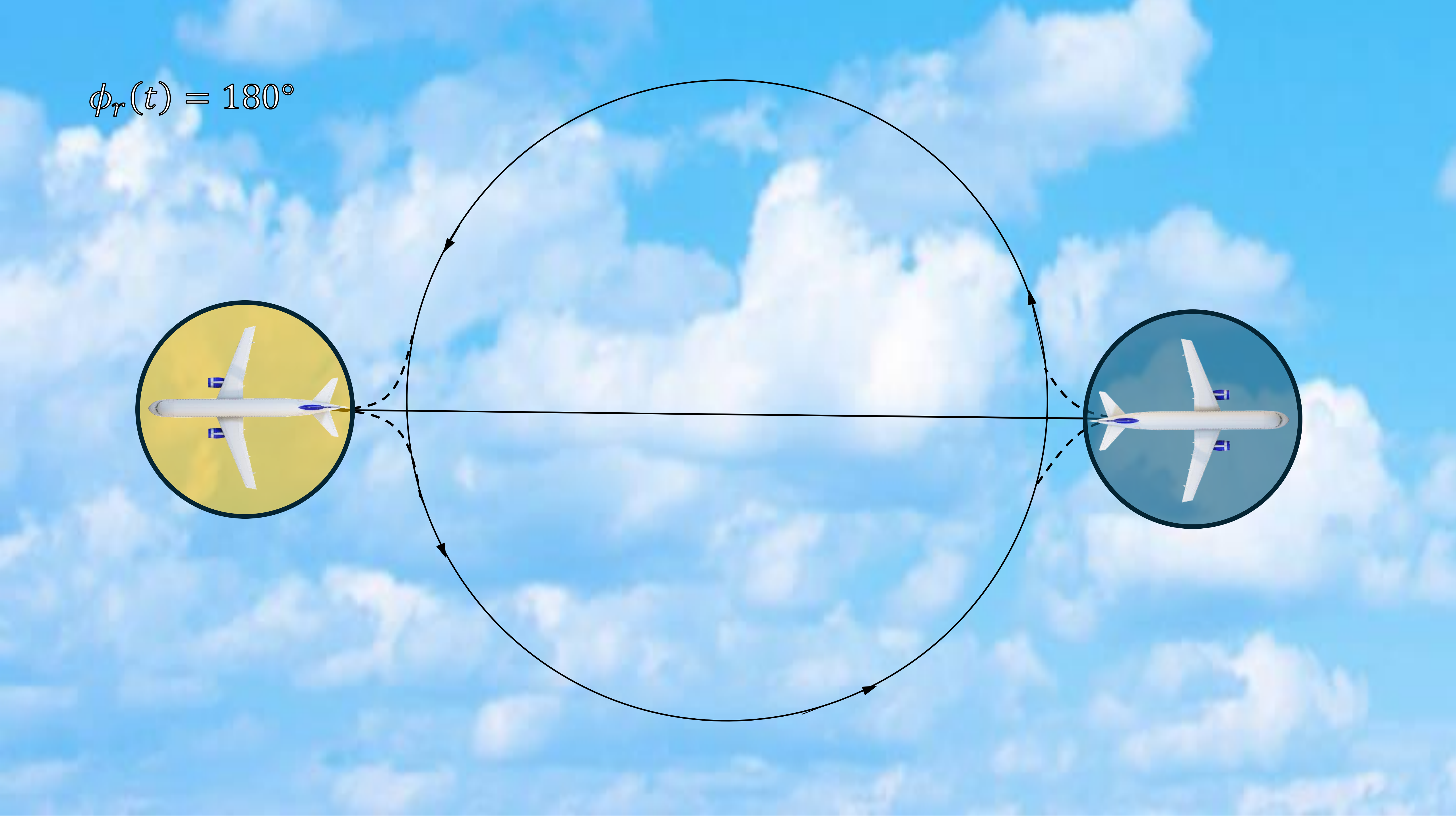

$\phi_r(t) = 180°$
Conflict Zone

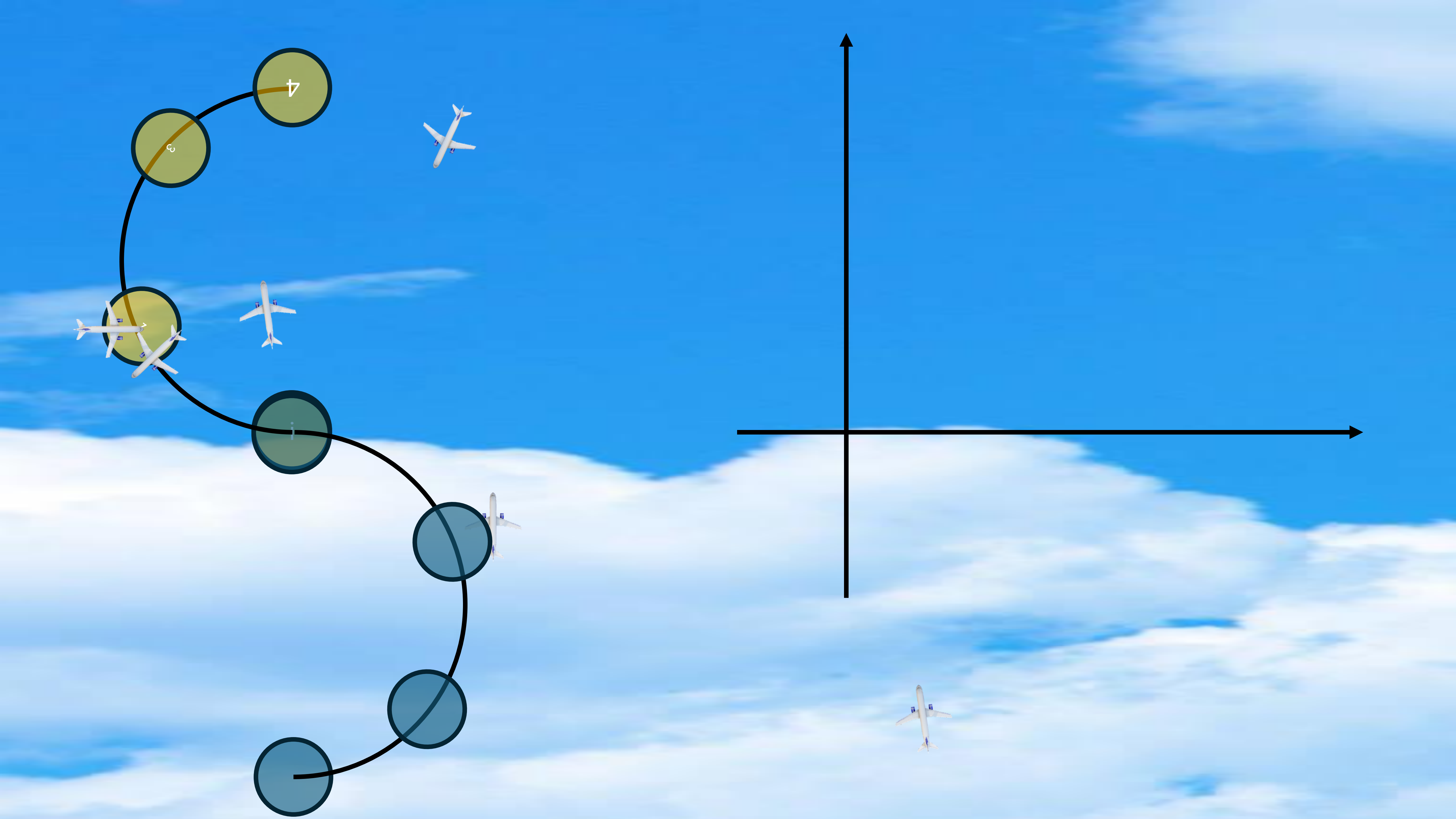

$\phi_r(t) = 180°$

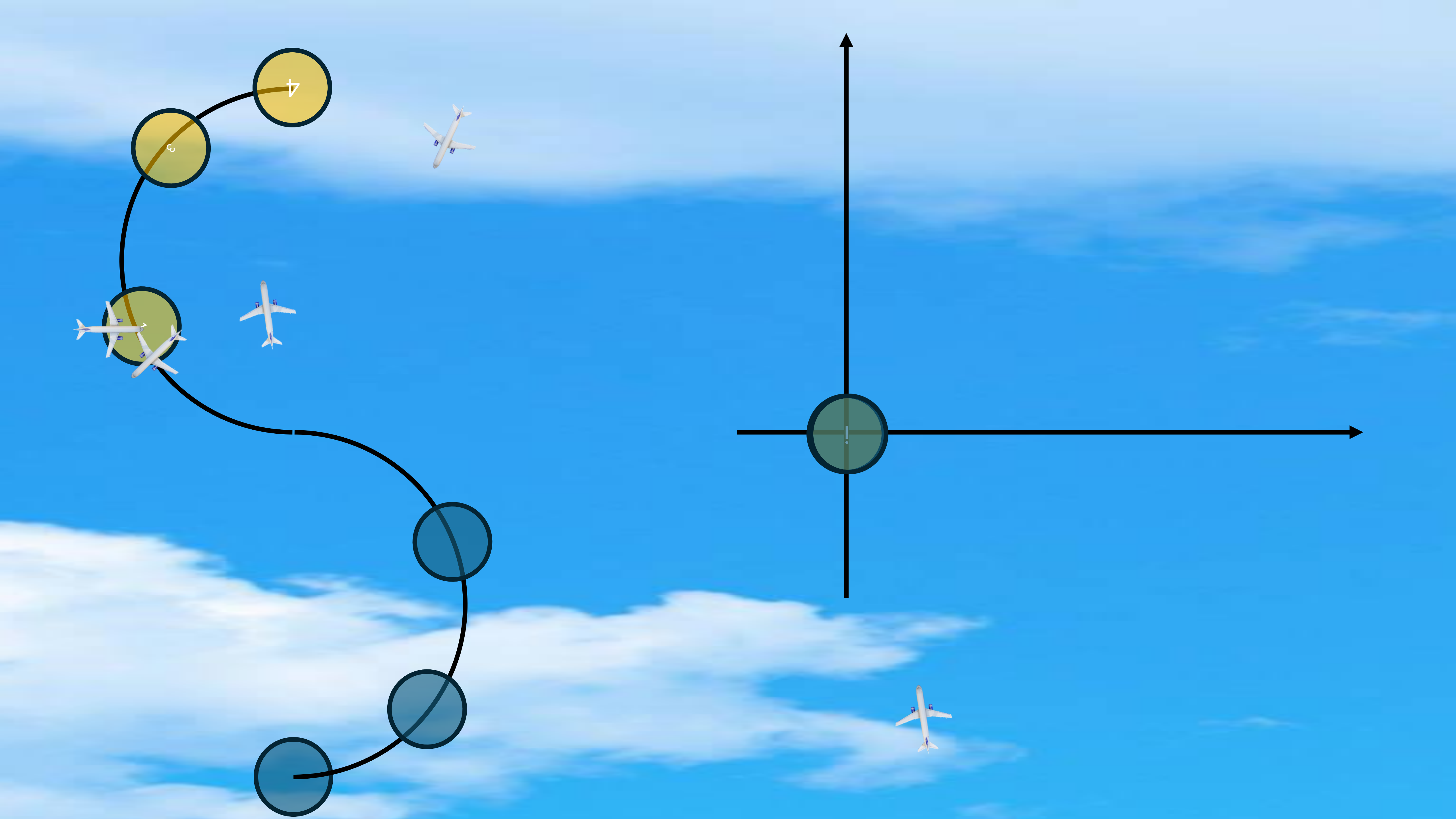

$\phi_r(t) = 180°$

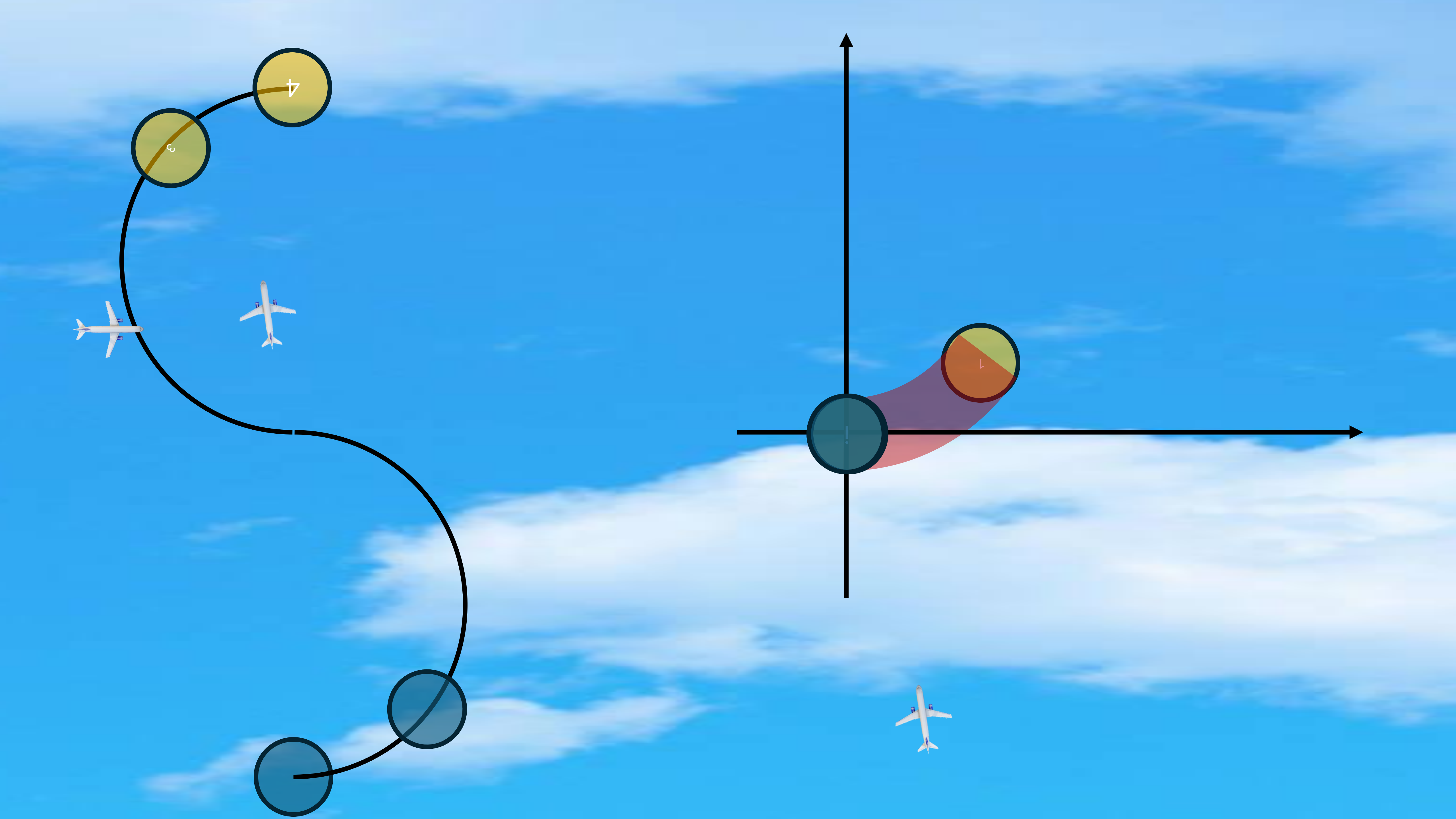

$\phi_r(t) = 180°$

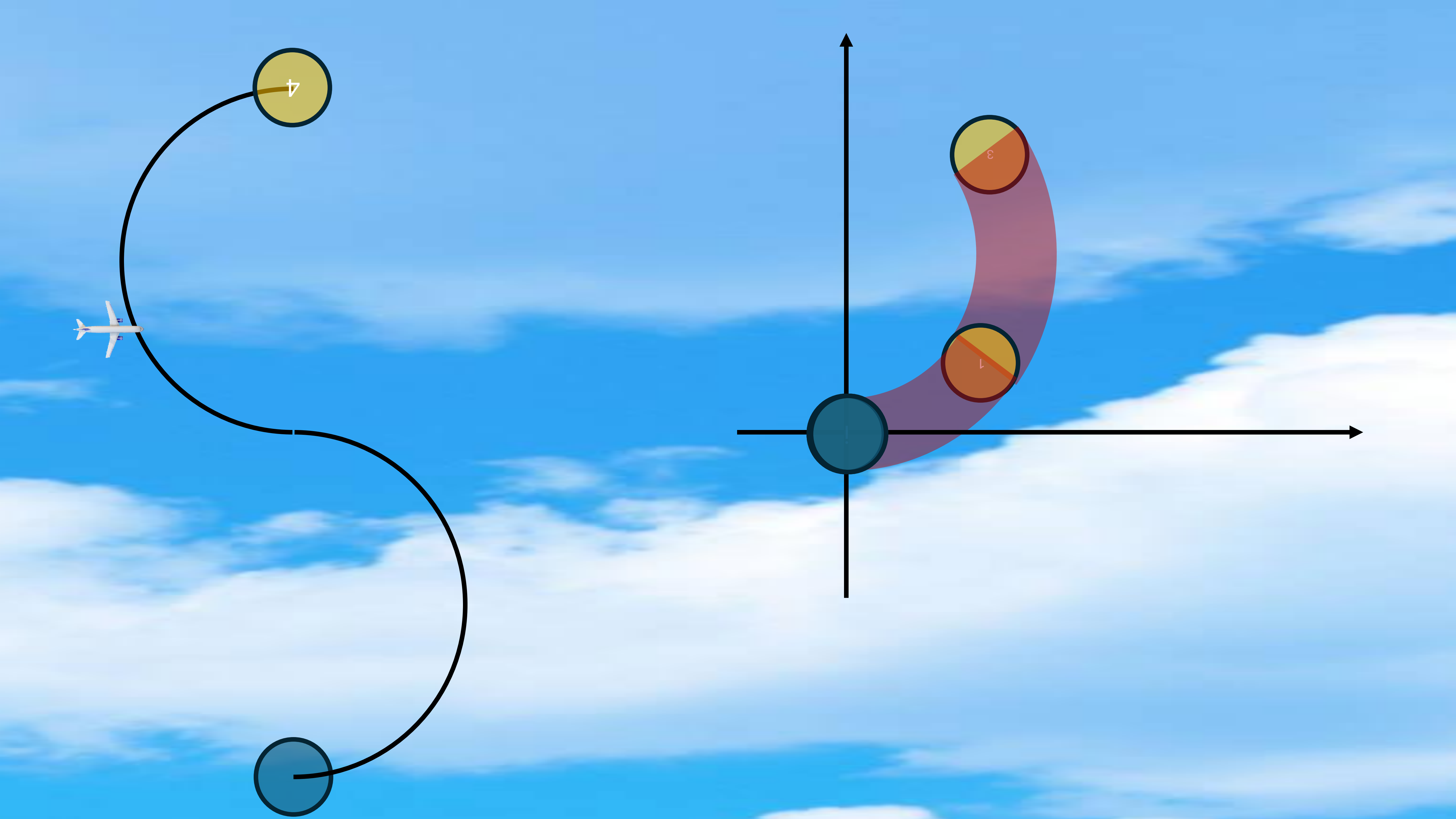

$\phi_r(t) = 180°$

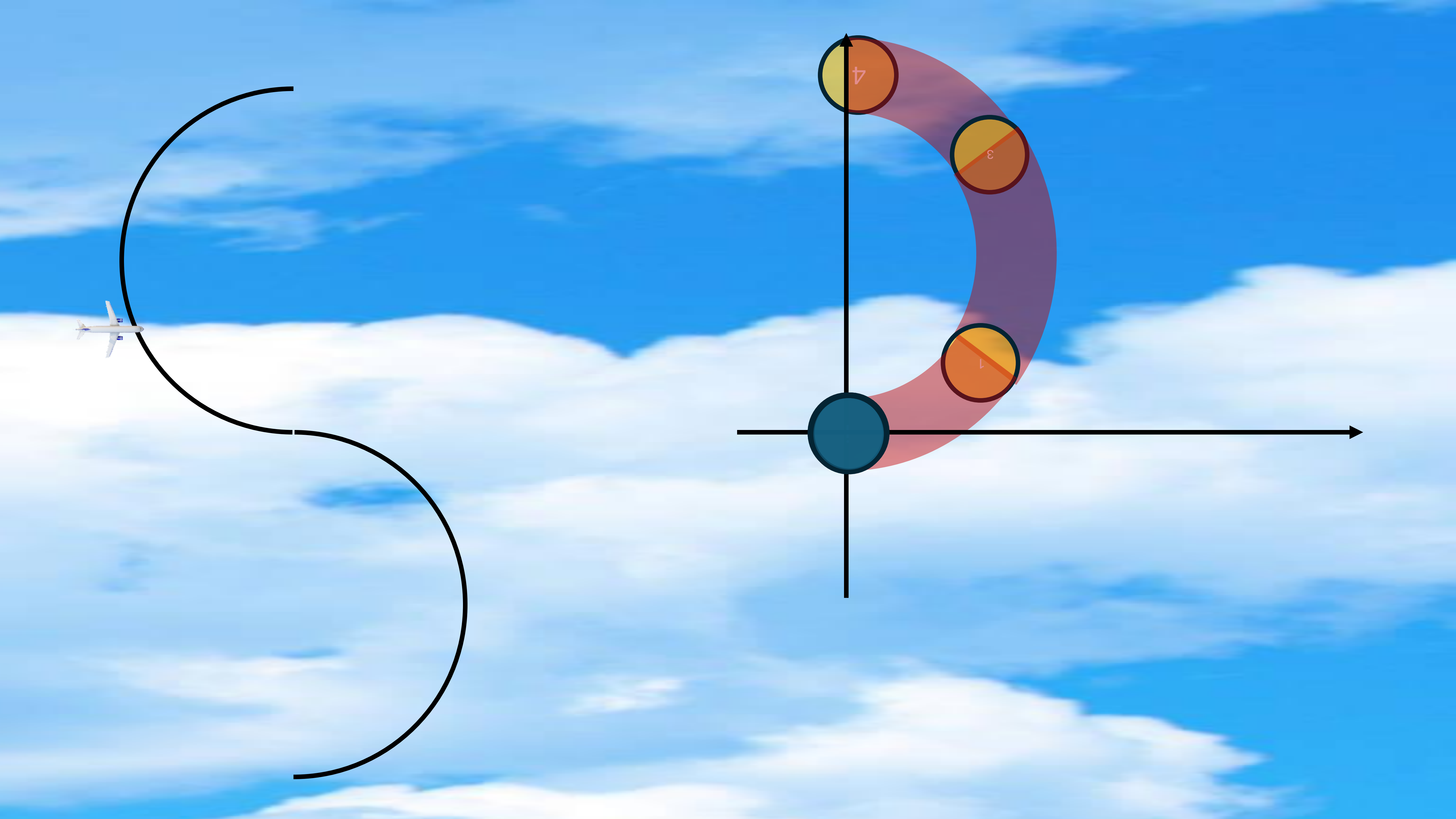

$\phi_r(t) = 180°$








4
3
1



4
3
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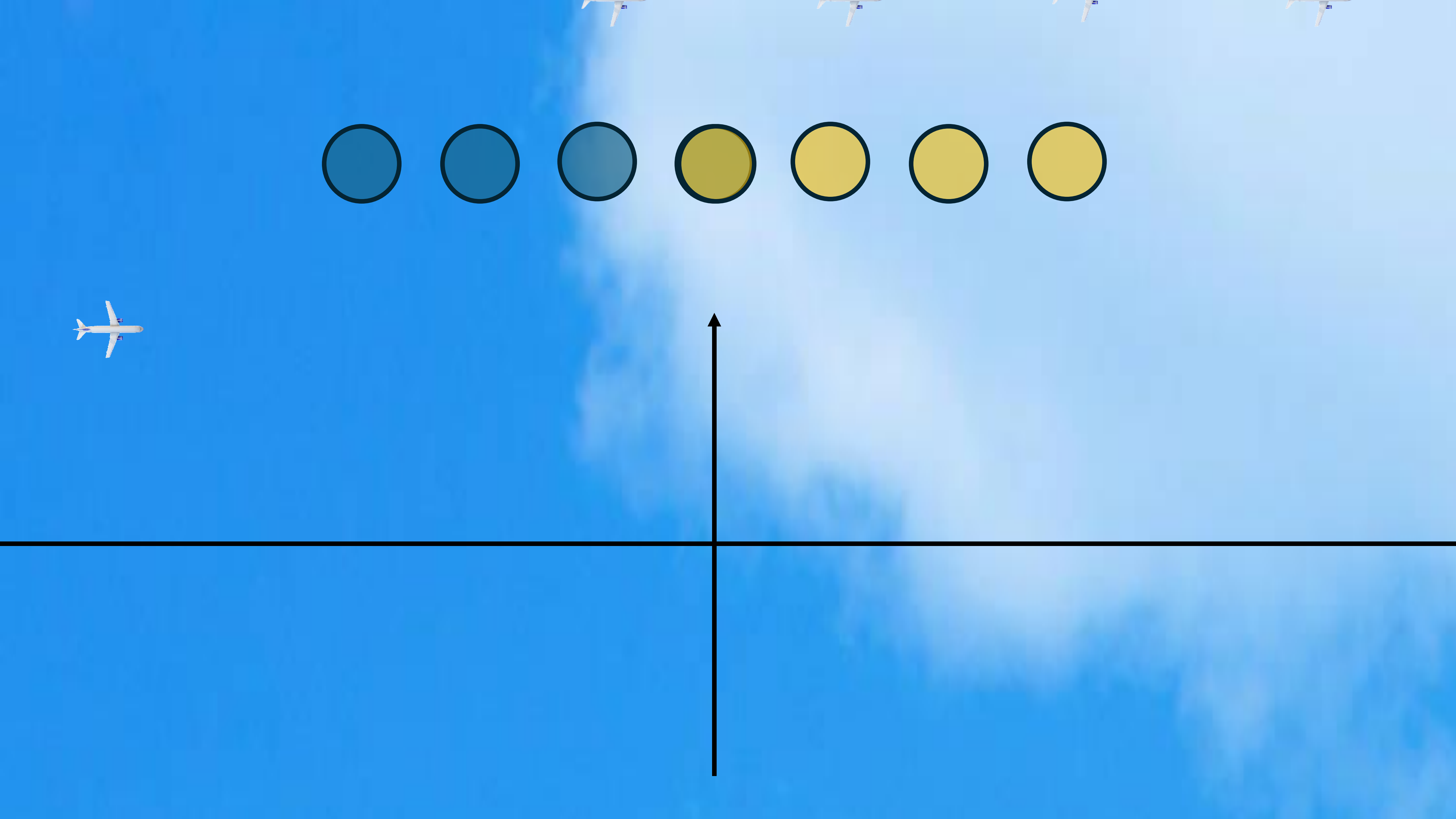
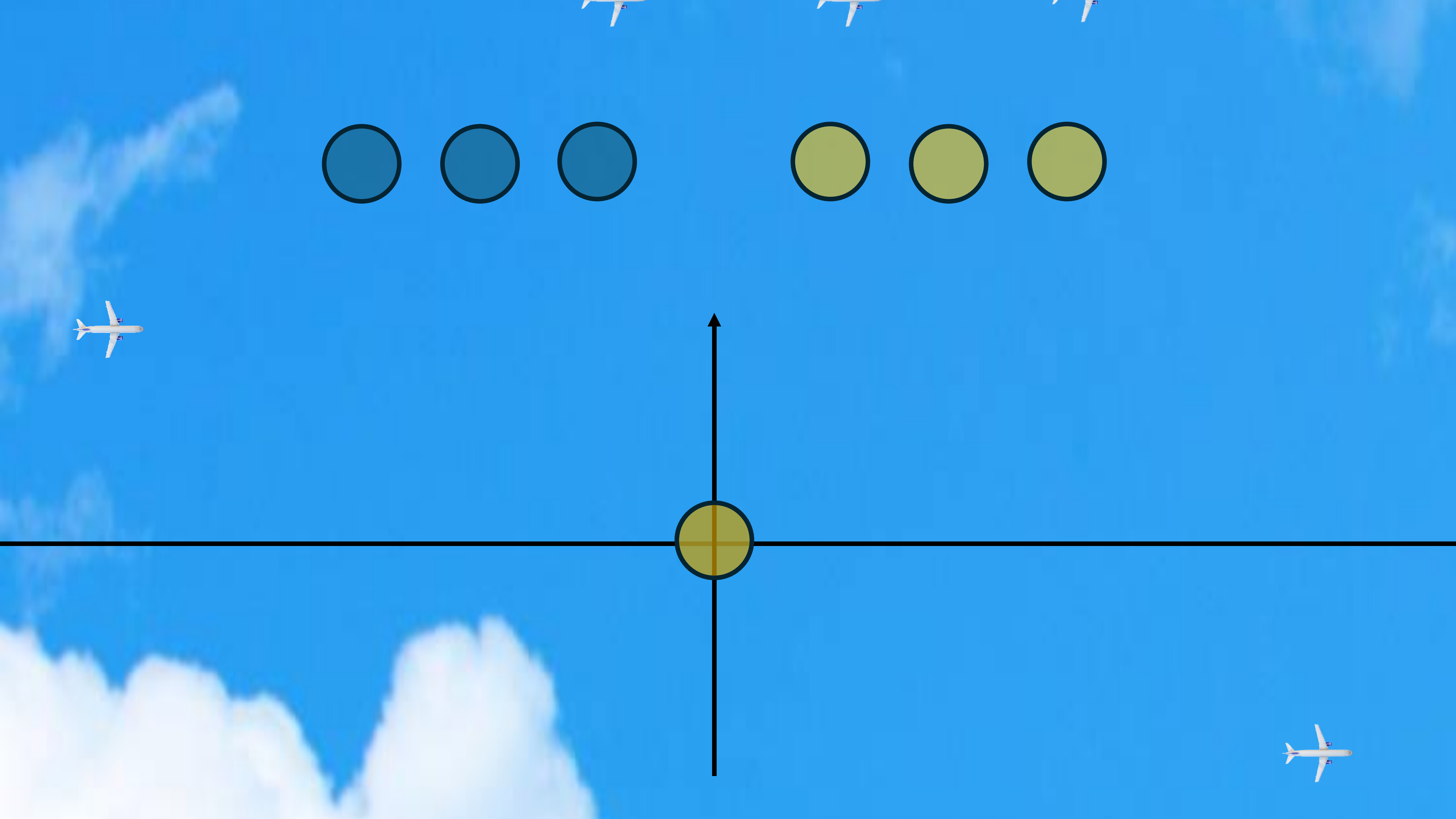
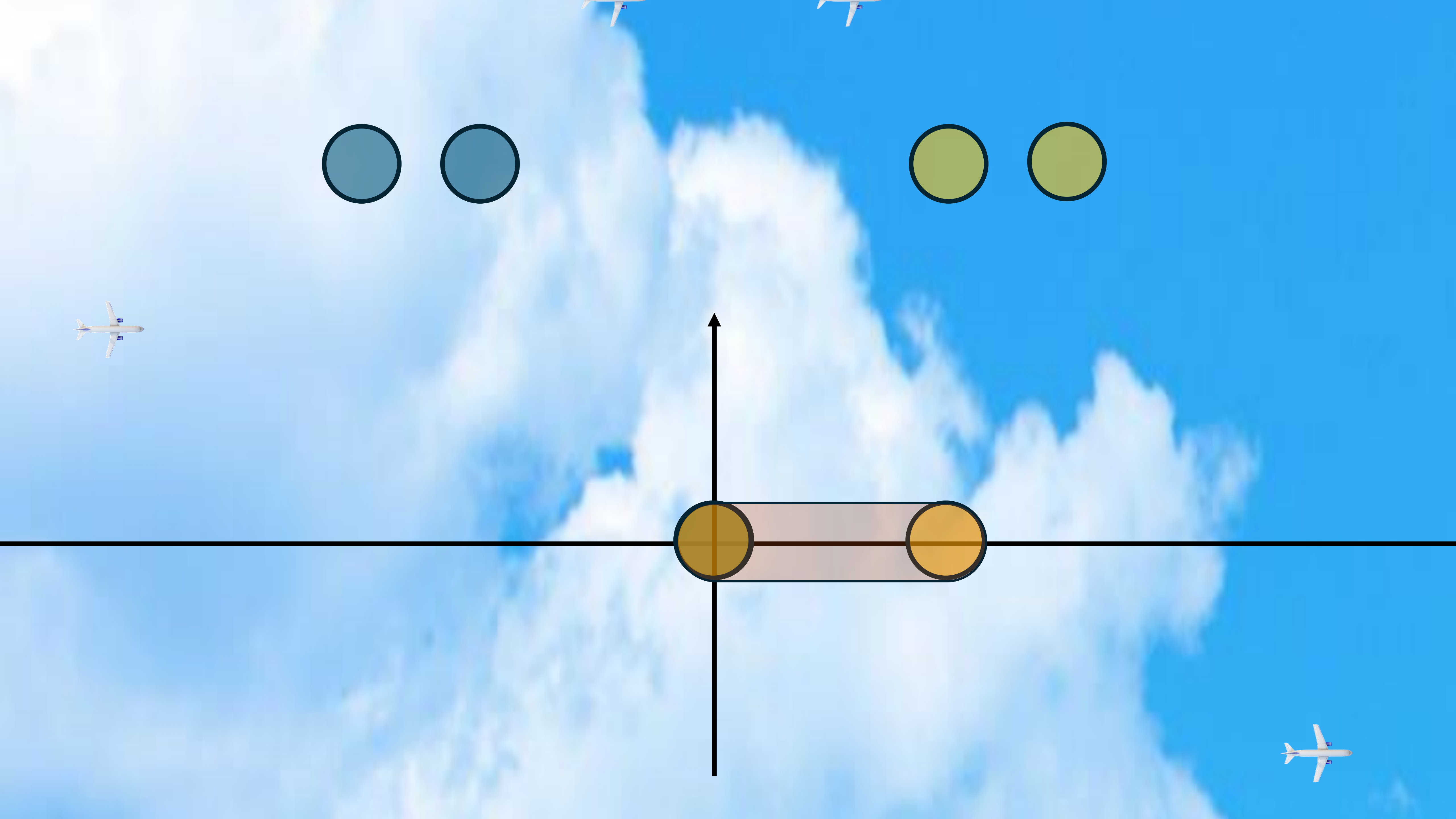
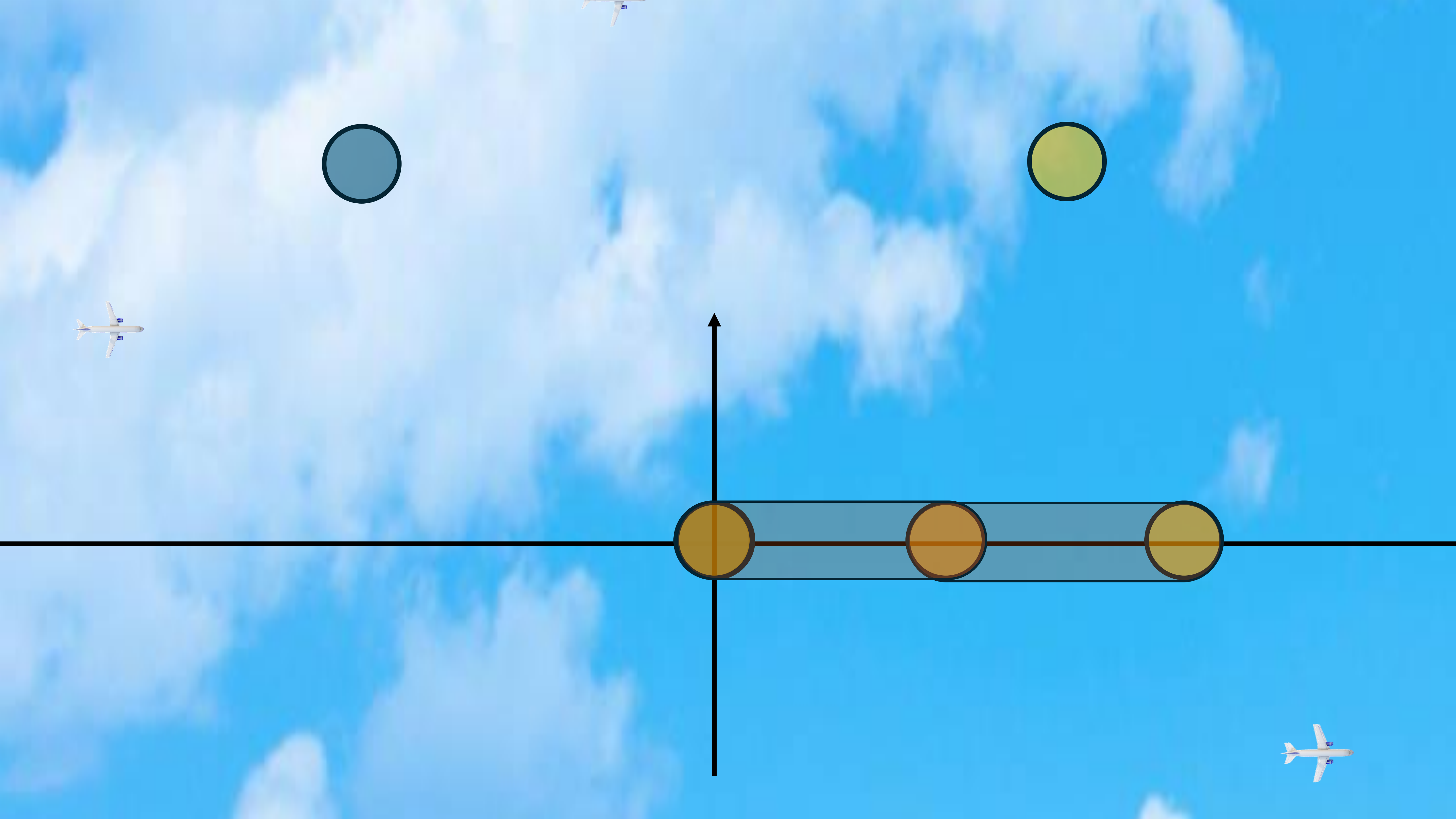
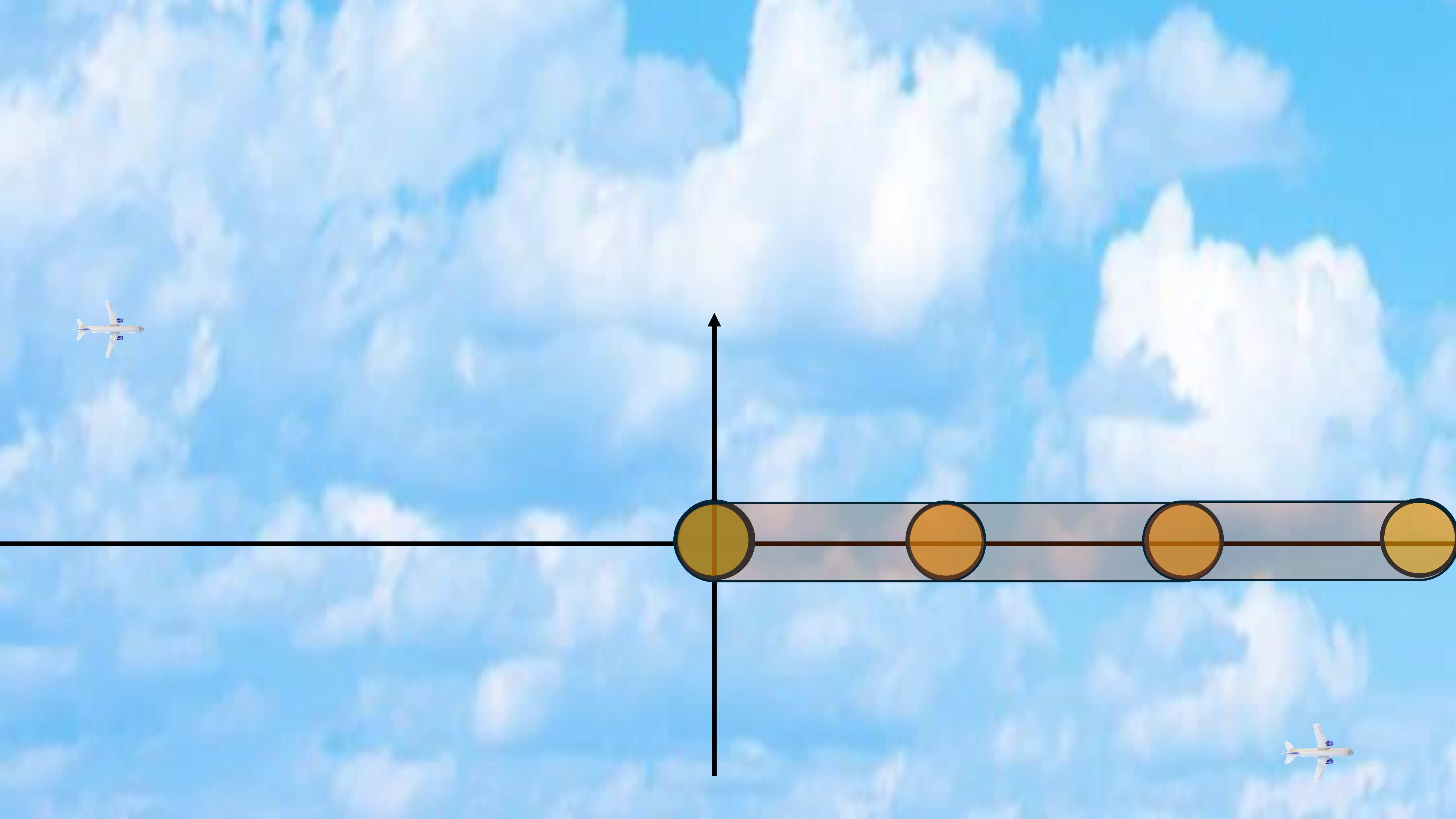
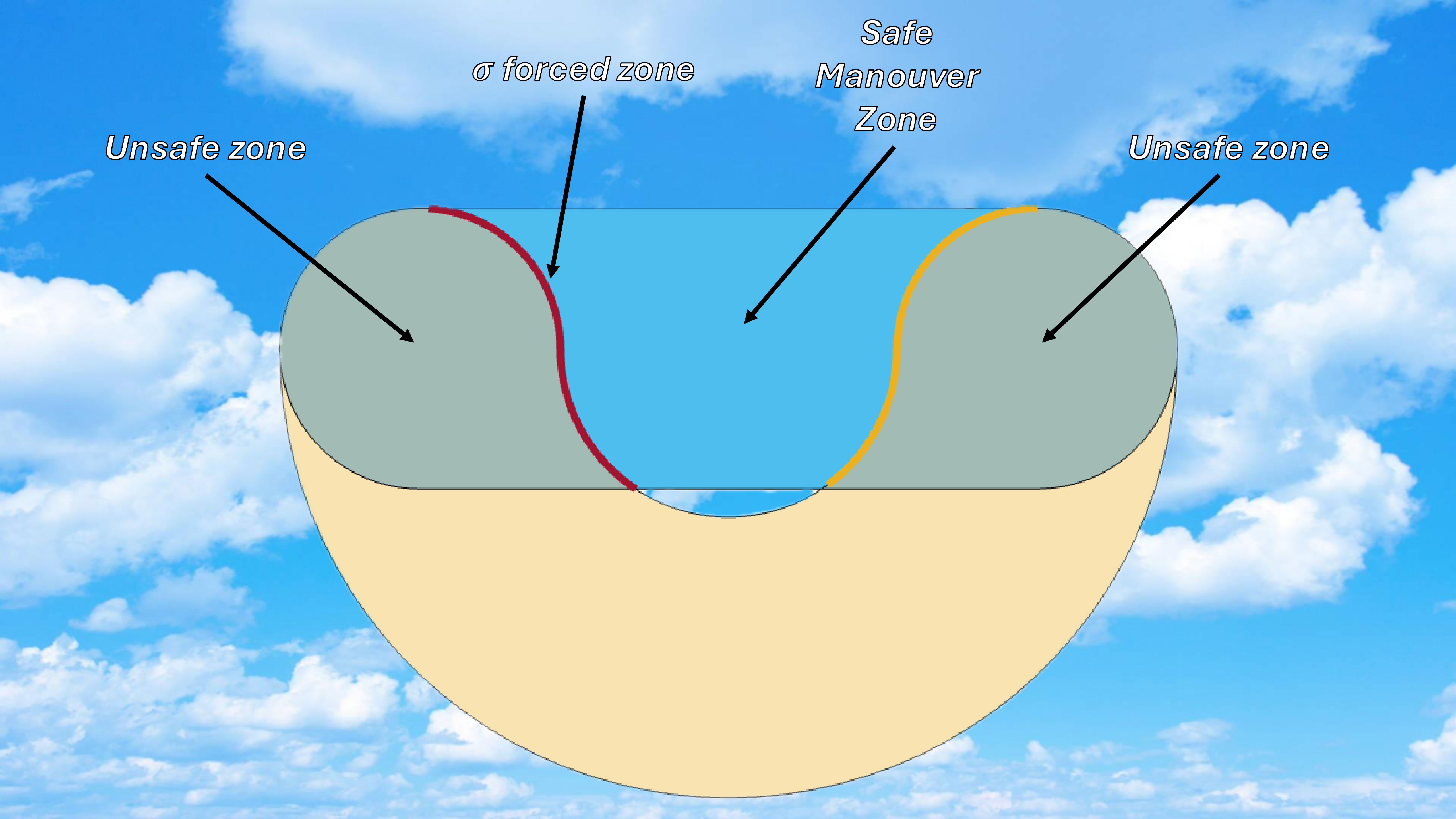











σ forced zone
Safe
Manouver
Zone
Unsafe zone
Unsafe zone

t_{min} calculation

t_{min}:

Consider a collision at t = 0 in q_1

Backward integration until we exit the unsafe zone → $x(t_{min})\ y(t_{min})$

Considering the constraint $x^2(t) + y^2(t) \geq r^2$ →

$$t_{min} = -\frac{r}{v}\sqrt{\frac{1}{2(1-\cos(\phi_r))}}$$

R_{min} calculation

Radius Relation:

Consider a collision at t = 0 in q_1

Backward integration until we exit the unsafe zone →

$x(t_0)$
$y(t_0)$

Forward integration in q_2 to avoid the collision

Considering the constraint

$x^2(t) + y^2(t) \geq r^2$ →

$$(4R - vt_0)^2 \geq \frac{r^2}{2(1-\cos(\phi_r))}$$

Case I: Last Second Manouver

Maximum time for collision avoidance:

$t_{max} = 8.75\ s$

Miniumum curvature radius:

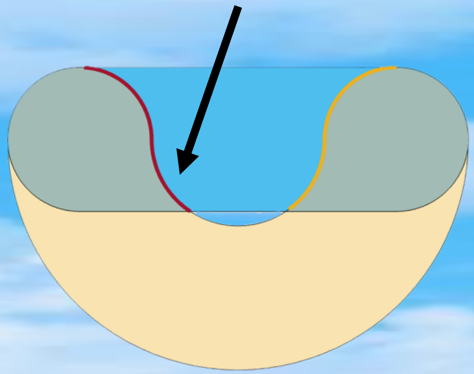
$R_{min} = 2.5\ miles$

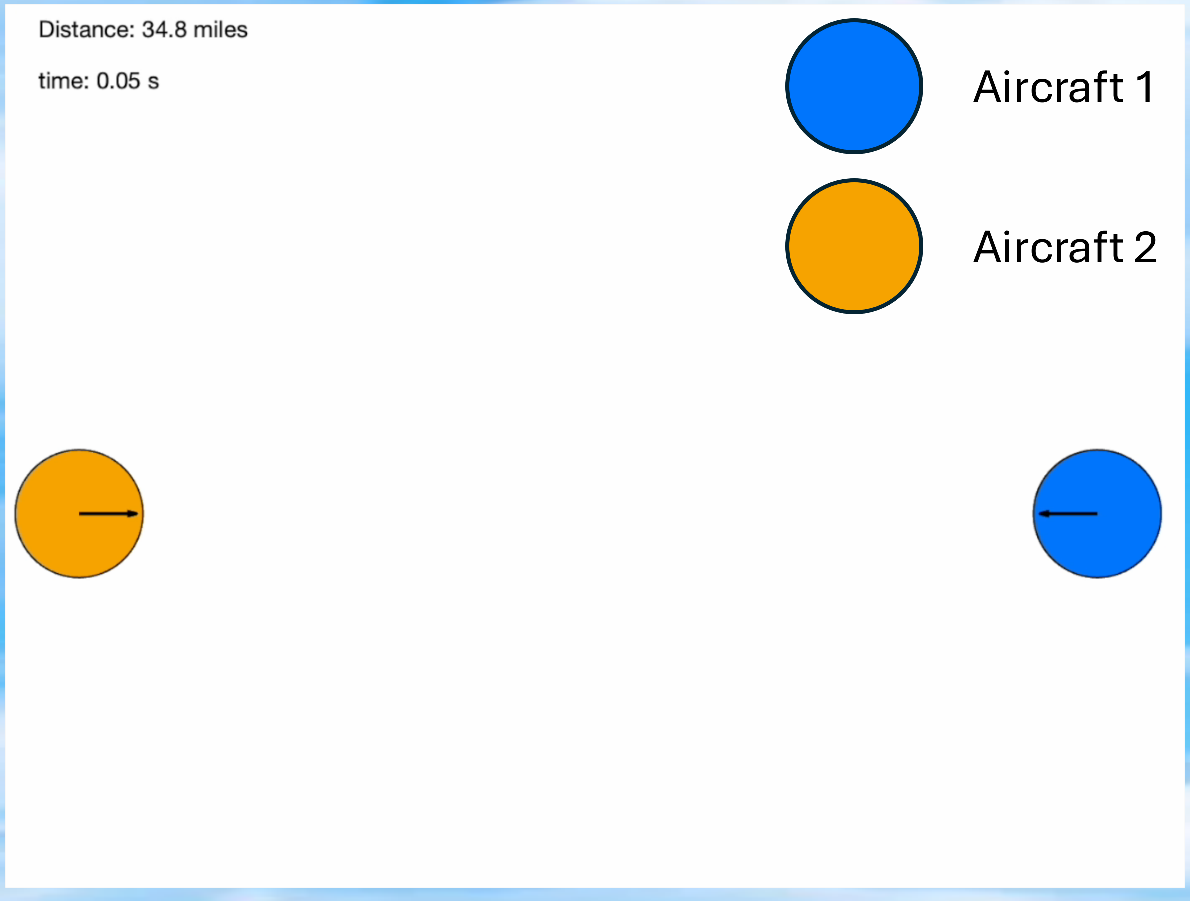
Case:

$t = t_{max}$

$R = 5\ miles$

σ *forced*





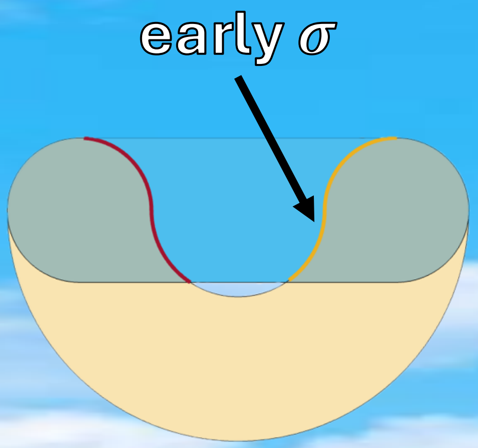
Case II: Early Manouver

Maximum time for collision avoidance:

$t_{max} = 8.75\ s$

Miniumum curvature radius:

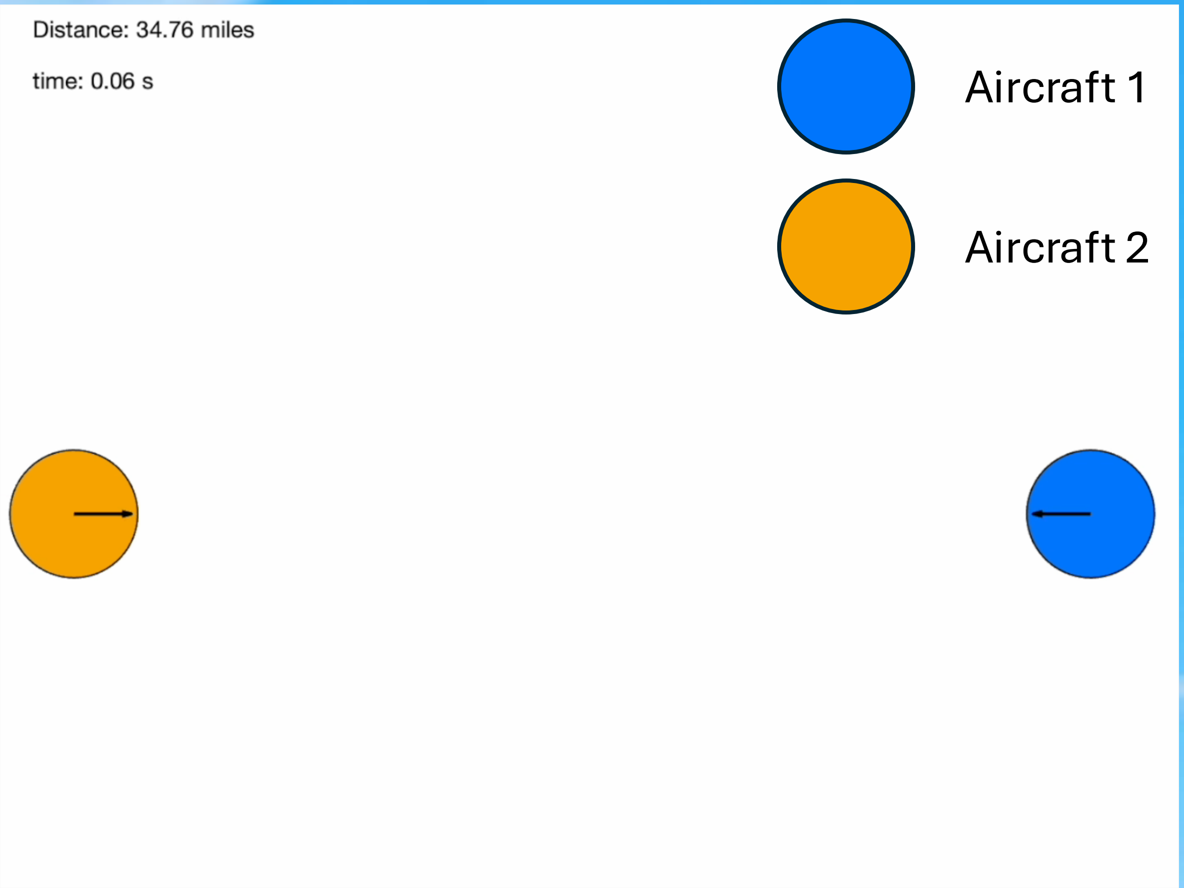
$R_{min} = 2.5\ miles$

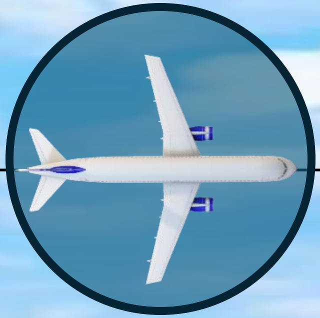


Case:

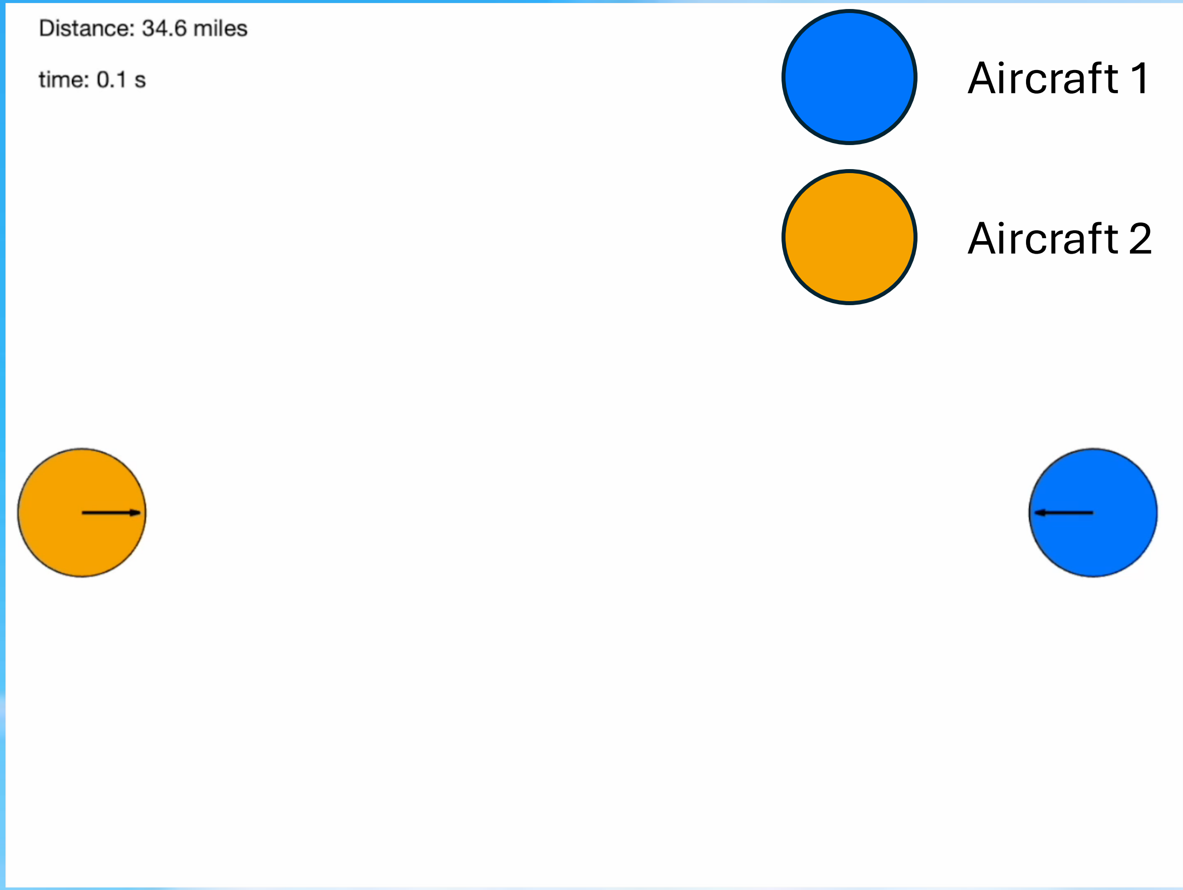
$t = t_{min} = 6.25\ s$

$R = 5\ miles$





Case III: Extreme Manouver



Maximum time for collision avoidance:

$t_{max} = 8.75\ s$

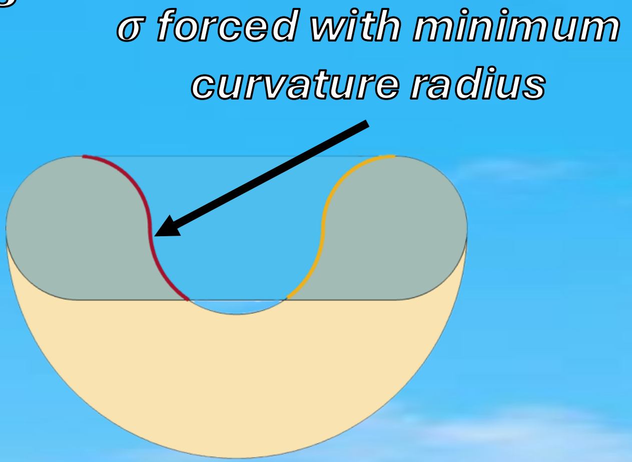
Miniumum curvature radius:

$R_{min} = 2.5\ miles$

Case:

$t = t_{max}$

$R = R_{min}$



Case IV: Aircraft crash

Maximum time for collision avoidance:

$t_{max} = 8.75\ s$

Miniumum curvature radius:

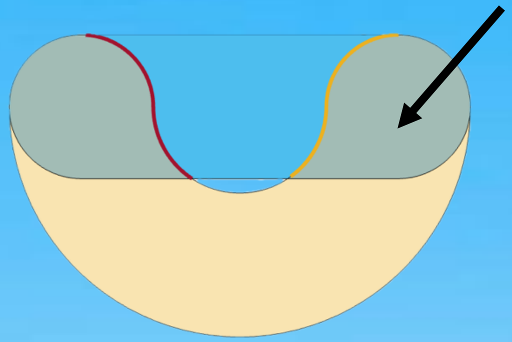
$R_{min} = 2.5\ miles$

Case:

$t = 5\ s$

$R = 5\ miles$

σ given too soon



THANKS

Carlo La Sala - Valerio Lubrano - Matteo Scuderi