Darmstad, Asgardia 14 October 2019

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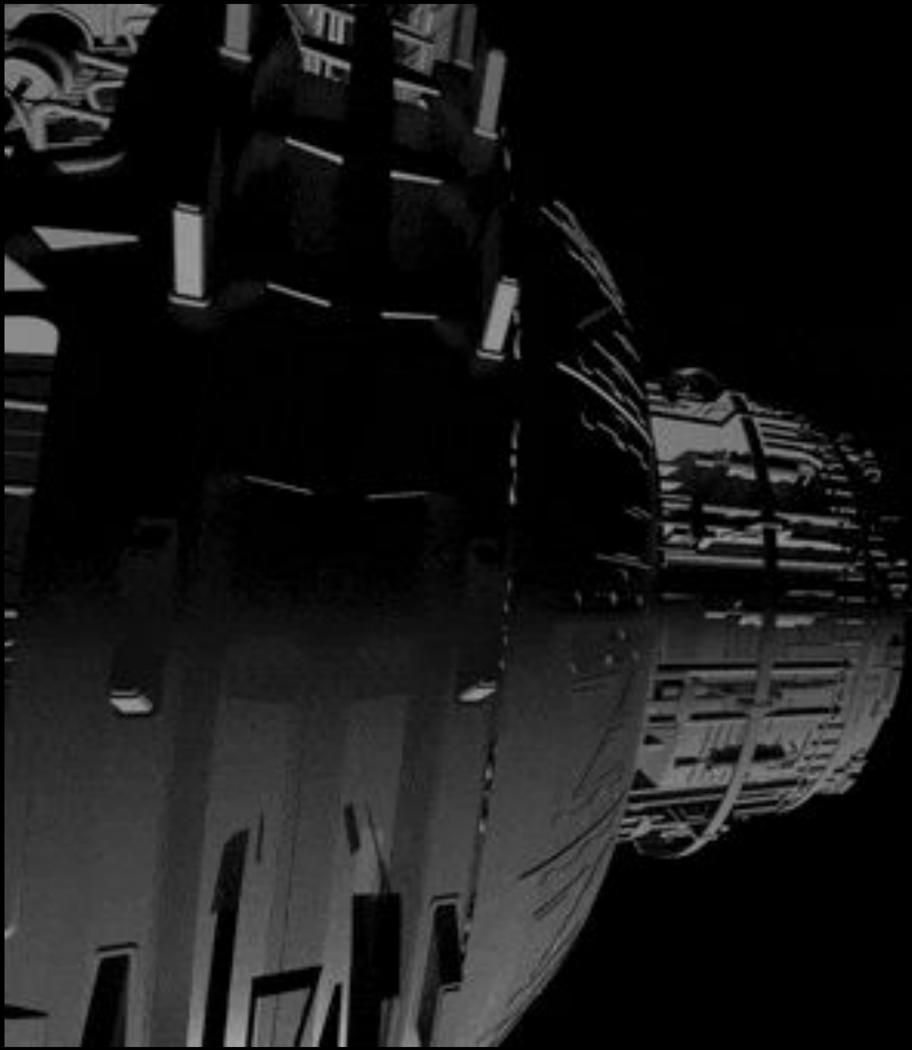
Investigation of the Coriolis Effect in Rotating Space Platforms for Space travel

Tigran Mkhoyan

TU Delft



Previous work in Coriolis effect and centrifuges

Mitigating the Coriolis Effect in Human Centrifuges by coherent G-misalignment

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Desdemona BV

Human centrifuges: examples

conventional: passive

9G 2-DOF
(CML Soesterberg)

- Pilot has no control
- Passive scenario (9G certification)

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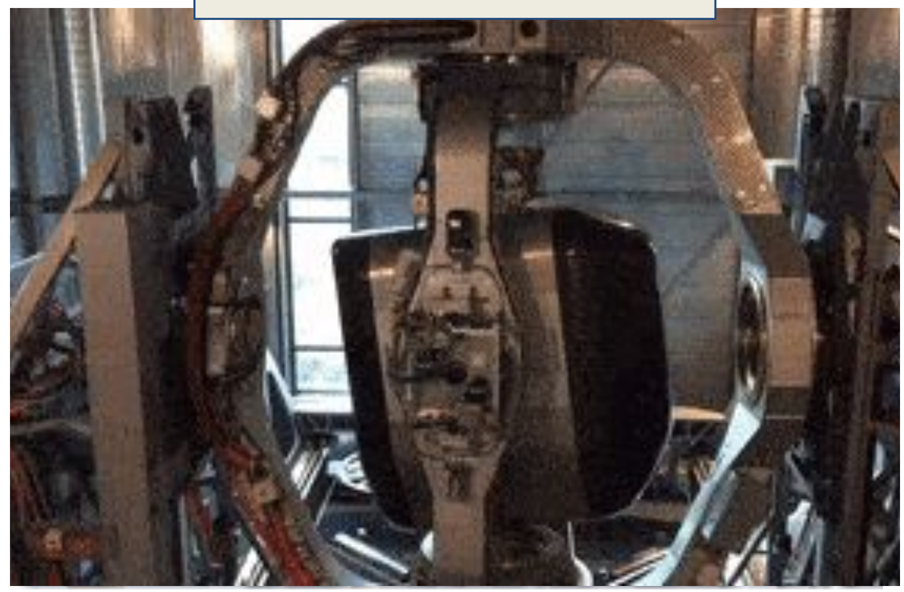
6-DOF: active



6-DOF Desdemona Simulator
(Desdemona BV Soesterberg)

- Pilot has control
- Extended motion envelope
- Active scenarios:
  - High-G maneuvering (F-16, Eurofighter)
  - Upset Recovery (Boeing 737)

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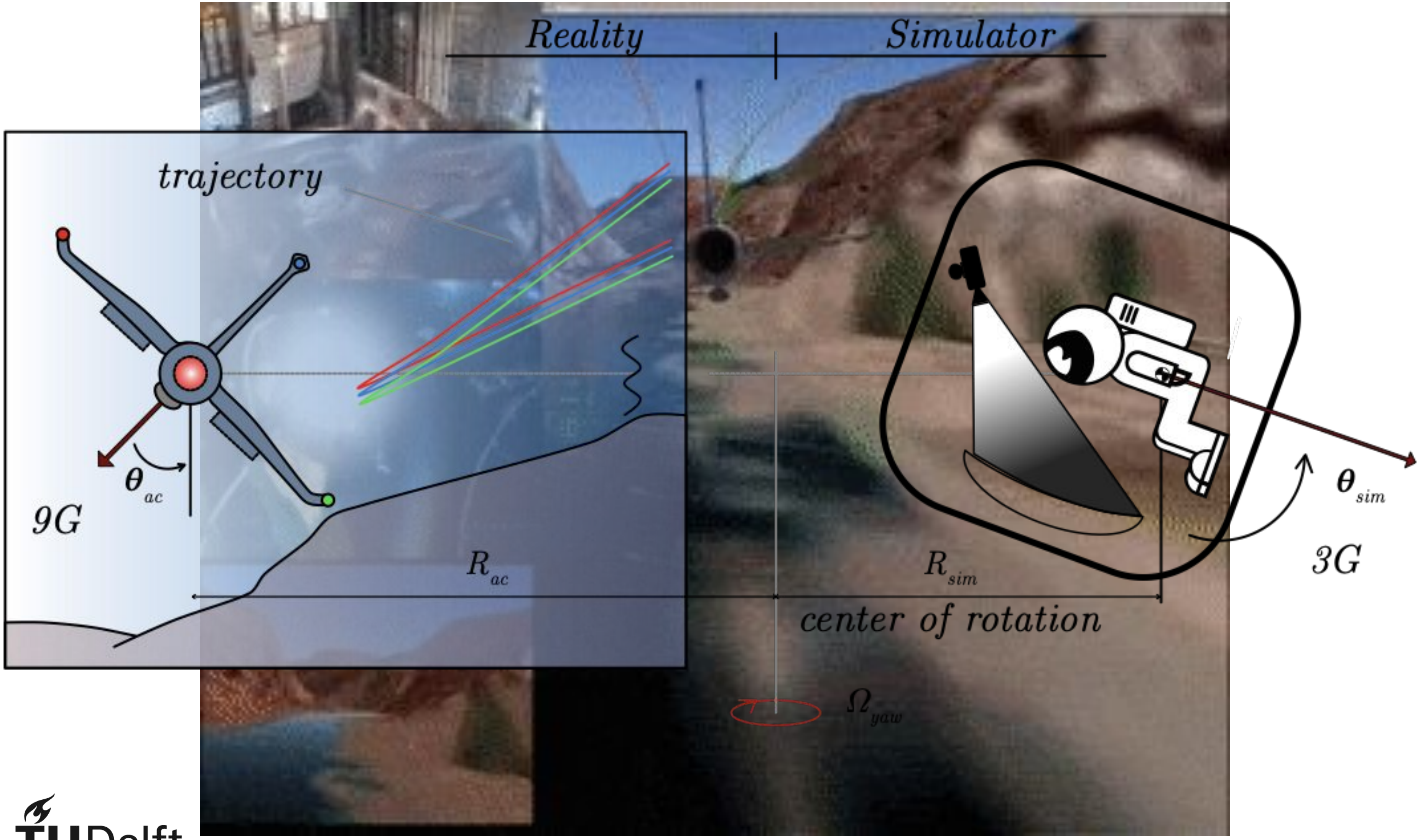
Cueing high-G maneuvers: example



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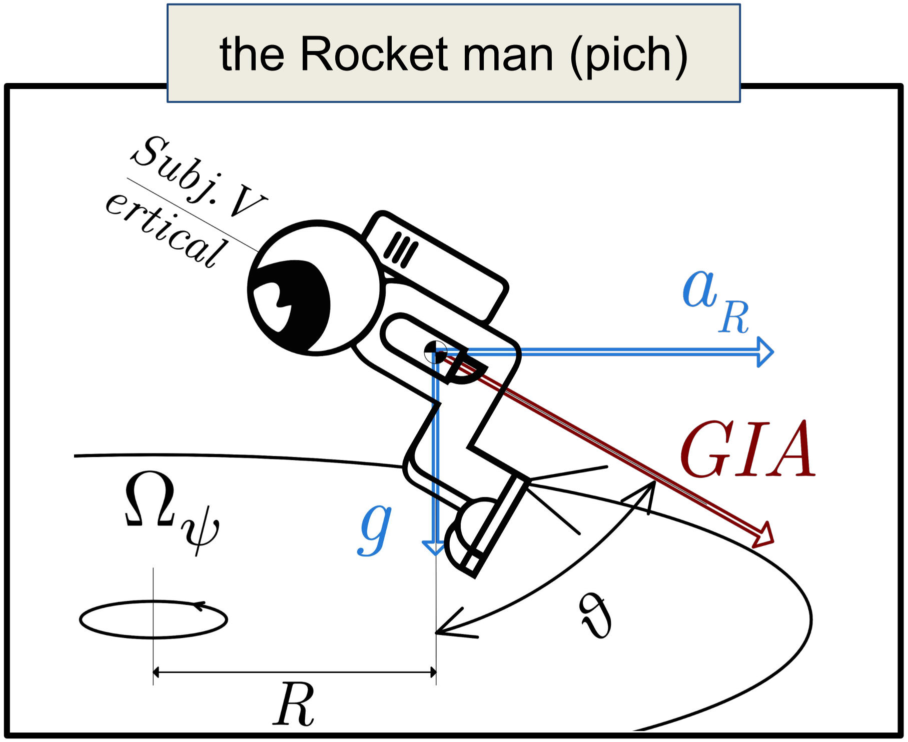
Why alignment of G-vector (GIA)?

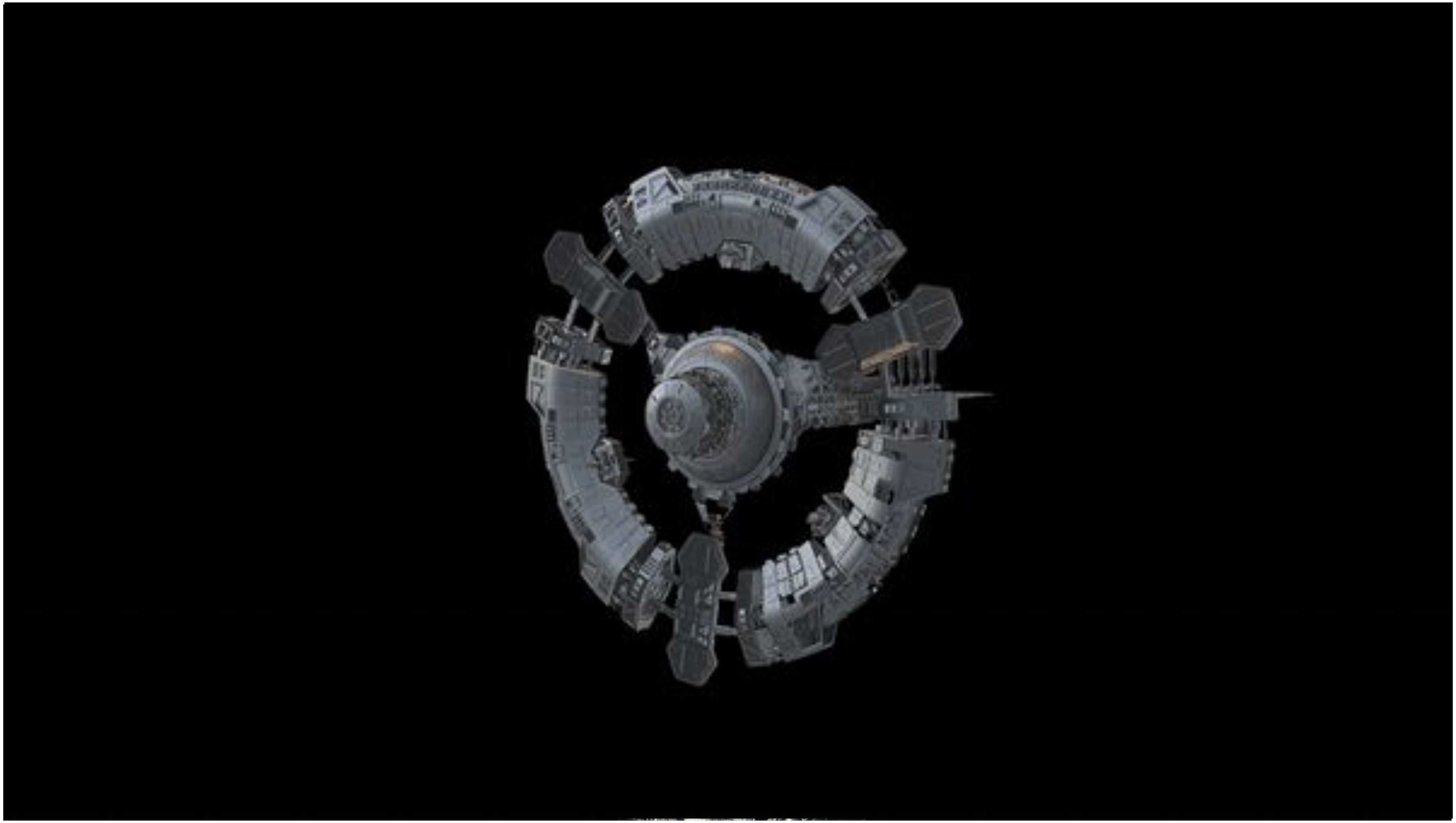
The GIA (Gravito-Inertial Acceleration) and cabin alignment

$$GIA = \sqrt{{a_t}^2 + {a_R}^2 + g^2}$$

$$\theta_{cabin} = \arctan\left(\frac{a_R}{g}\right) = \arctan\left(\frac{(\Omega_\psi)^2 R}{g}\right)$$



Space? Artificial Gravity, rotational

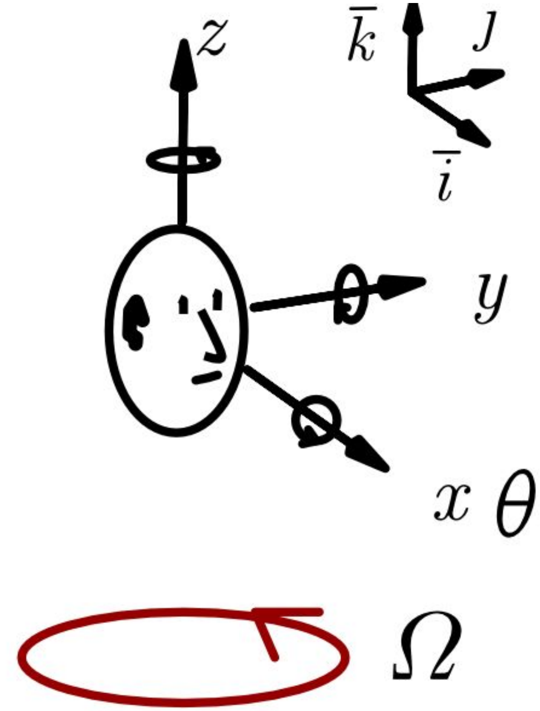


The problem: Coriolis effect

Head-centric Angular acceleration ${}^{h}\alpha$:

$$\begin{bmatrix} {}^{h}\alpha_X \\ {}^{h}\alpha_Y \\ {}^{h}\alpha_Z \end{bmatrix} = \begin{bmatrix} \ddot{\theta} \\ \Omega\dot{\theta}\cos(\theta) + \dot{\Omega}\sin(\theta) \\ -\Omega\dot{\theta}\sin(\theta) + \dot{\Omega}\cos(\theta) \end{bmatrix}$$

source: www.faa.gov



The problem: Coriolis effect

Test case: Spaceship-X (type: 2001, A Space Odyssey)

$$R = \sqrt{a_r + a_t + g}$$
$$R_{ss} = \sqrt{a_r + \cancel{a_t} + \cancel{g}}$$
$$R_{ss} = a_r = \omega_{ship}^2 r$$

Design for rotation:

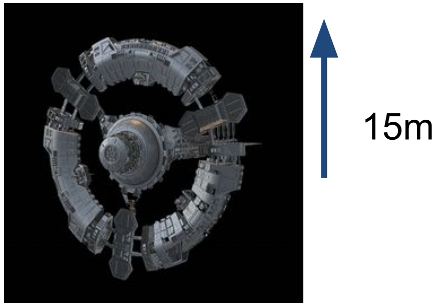
$$\omega_{ship} = \sqrt{\frac{R_{ss}}{r}}$$

Ship 1:
Radius r = 150 m
at 1600$/kg (Falcon 9 heavy) we have:

$$5440 \cdot 1000 \cdot 1600 = \$\mathbf{8.70\ bn}$$
$$5440[t]/63.2 = \mathbf{87\ flights}$$
$$\omega_{ship} = \sqrt{\frac{9.81}{150}} = \mathbf{0.26\ rad/s}$$

Ship 2 more realistic:
Radius r = 15 m
at 1600$/kg (Falcon 9 heavy) we have:

$$5440 \cdot 1000 \cdot 1600/10^2 = \$\mathbf{87.04\ million}$$
$$5440[t]/10^2/63.2 = \mathbf{1\ flight!}$$
$$\omega_{ship} = \sqrt{\frac{9.81}{15}} = \mathbf{0.99\ rad/s}$$



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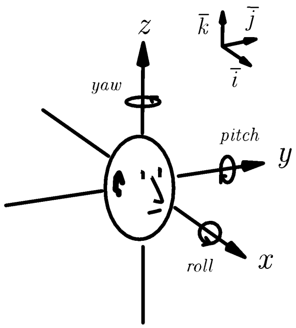
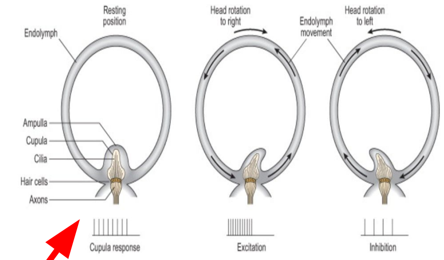
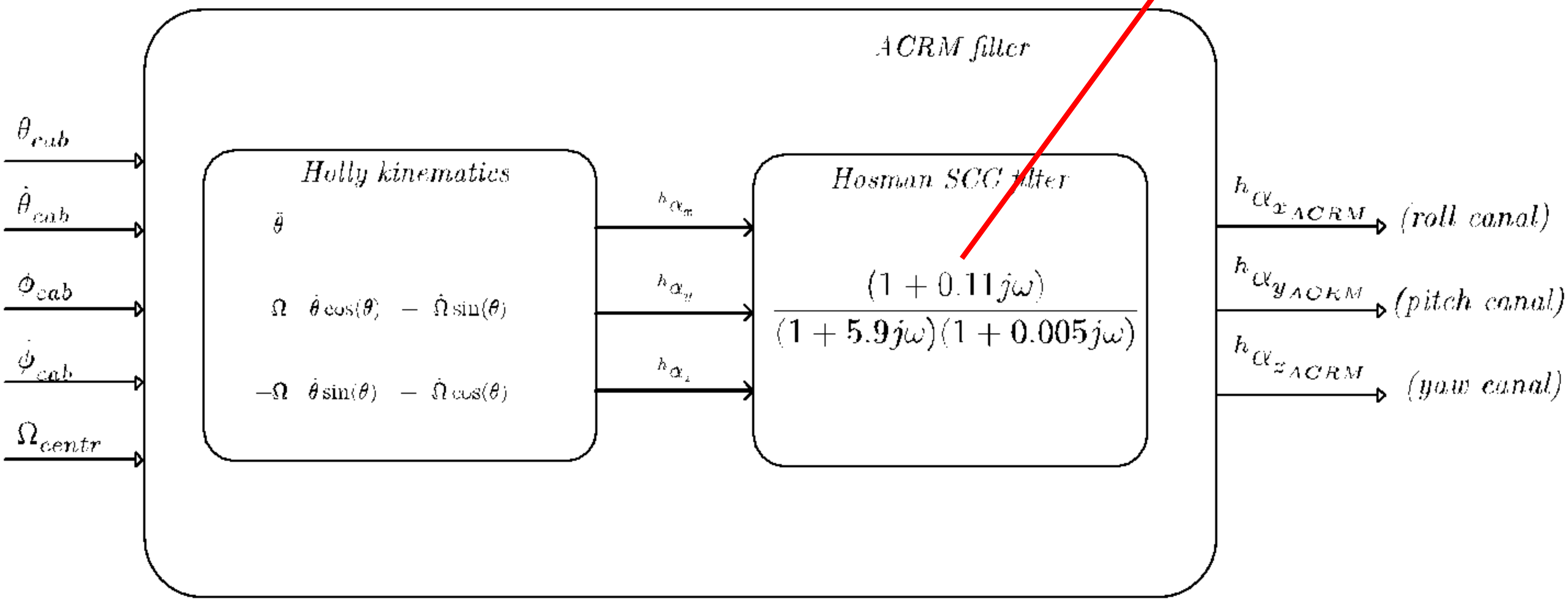
Will we experience coriolis effect in our hypothetical space ship (ship 2)?

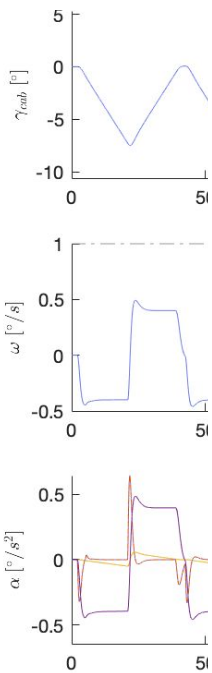
Perception filter ACRM

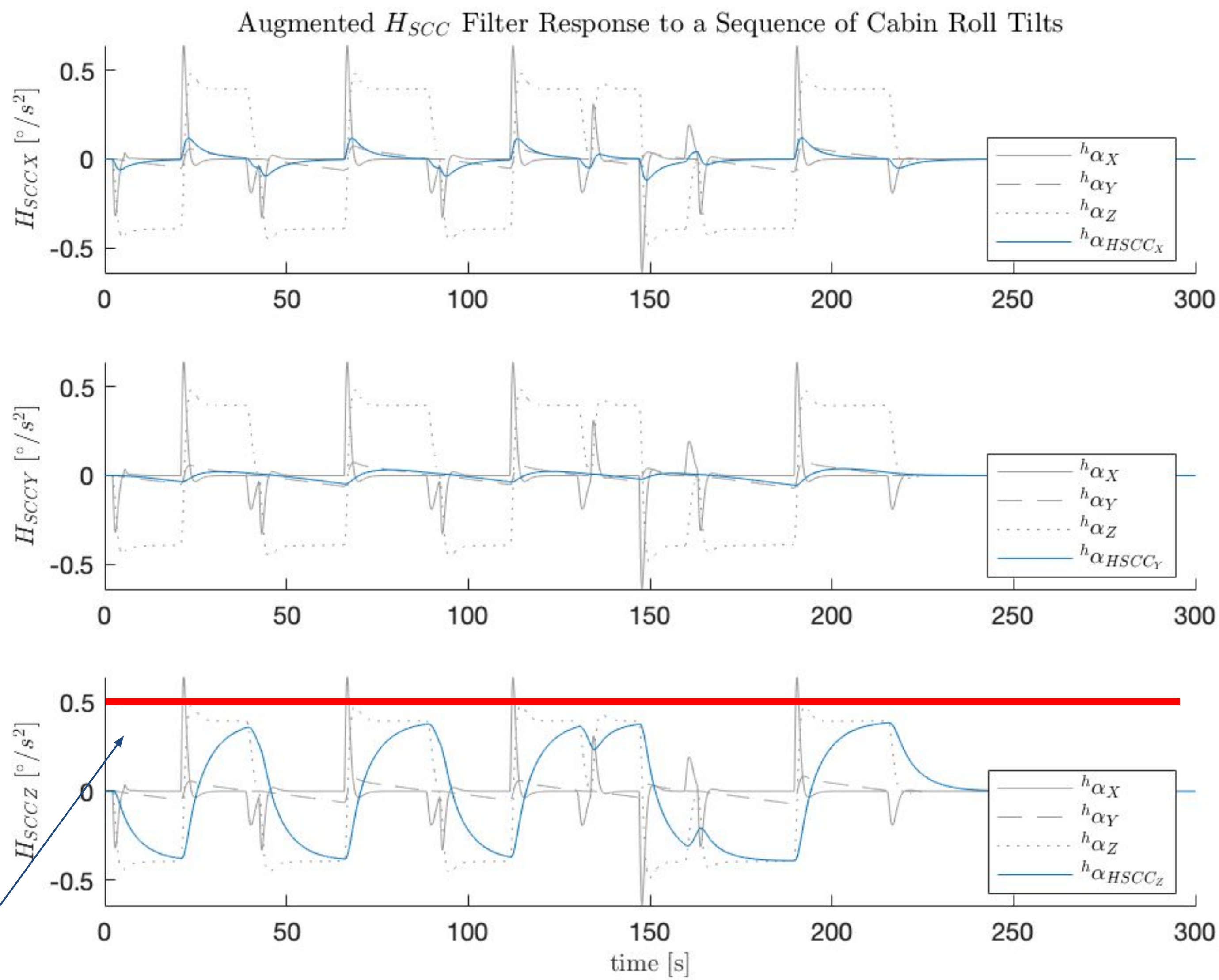






Simulation results: head tilts in ship 2





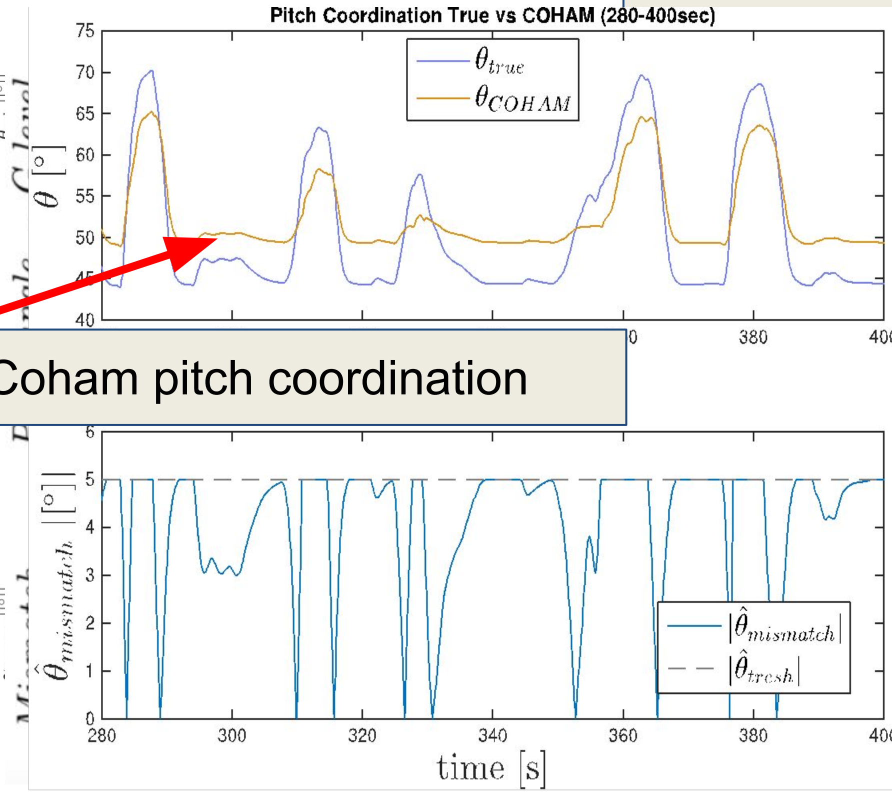
already close to **0.5 deg/s2** sensory threshold for 10 deg head tilt (Groen et al. 1948)

Is there a solution?

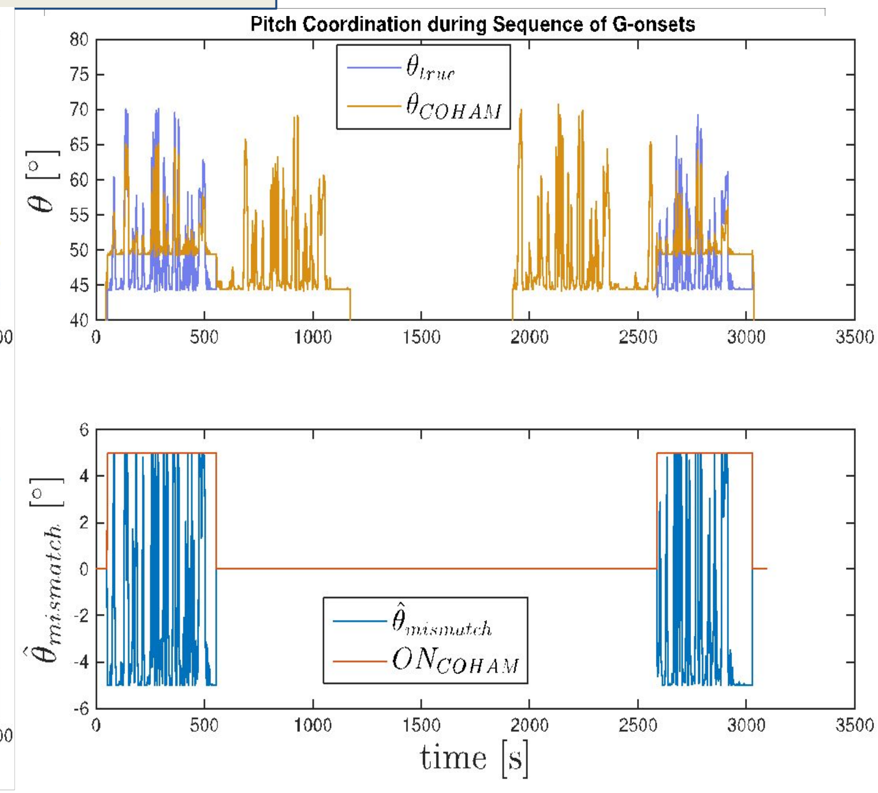
G-training: COHAM motion filter

Minimising pitch rotation: Two-Tailed Peak Flattening (TTPF)

Coham filter response



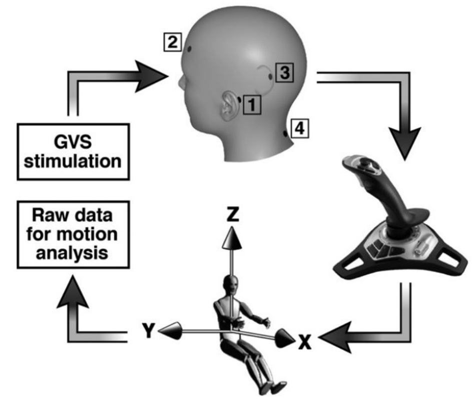
Coham pitch coordination



Galvanic Vestibular Stimulation (GVS)

<u>Mitigate</u> motion coupling: Motion simulators, Space Travel?

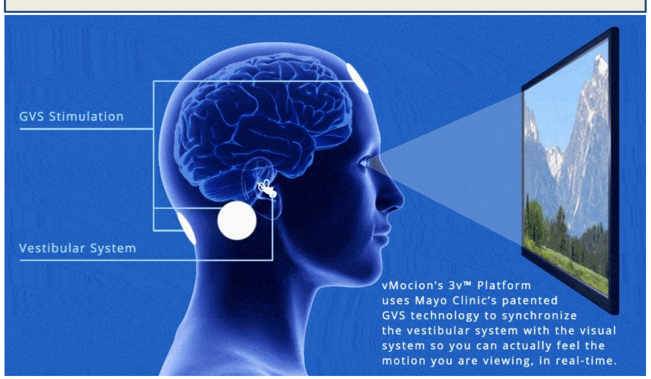
Oculo-Vestibular Recoupling to mitigate motion sickness:



(Cevette 2012)

<u>Induce</u> motion coupling: *VR, 4D experience, gaming*

vmocion 3*v*



source: vmocion

Project Morpheus PS4

source: phys.org

Conclusion

- Many possibilities exist
- Just to solve one problem
- Involves manipulating our sensory system
- Invasive and possibly non-invasive approach

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How far would you go to reach mars?