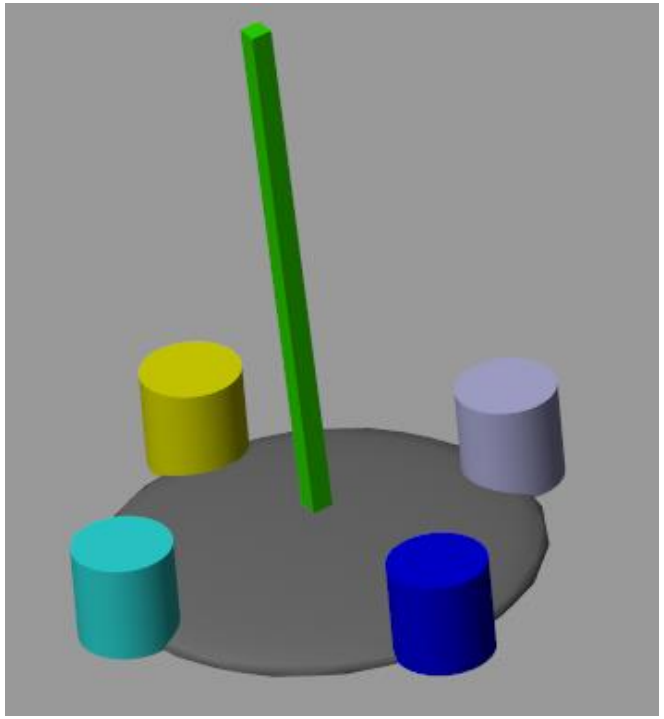
DEMO Guide and comments

- *QUADCOPTER balancing a PENDULUM*



Brad Horton
Engineer
MathWorks

Context

The context of the demo:

- Used for Edu engagements
  - Professors teach machine dynamics
  - Professors teaching Control

- Emphasise COMPUTATIONAL Thinking
  - symbolic toolbox usage for equation derivation
  - Simulink for simulating models containing the derived equations of motion

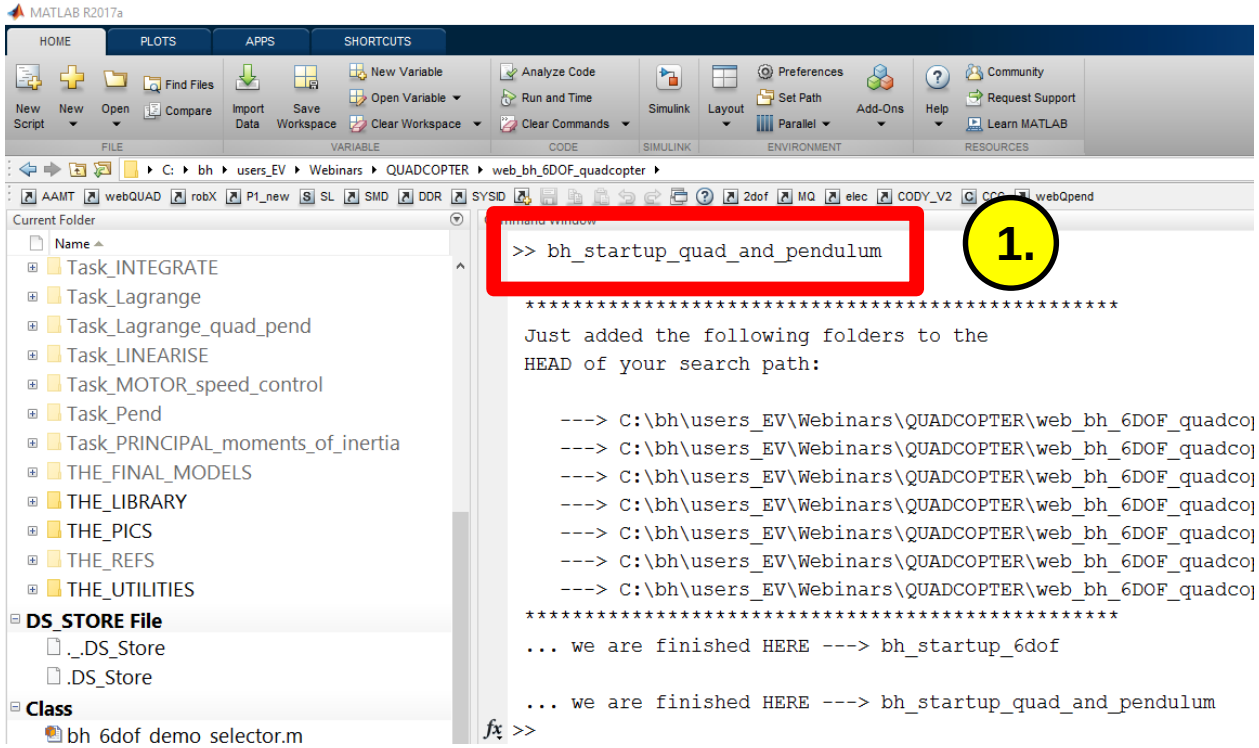
- Emphasize modelling choices
  - Hand derivations
  - Simscape models
    - Easy
    - Machine visualization/animations straight out of the box

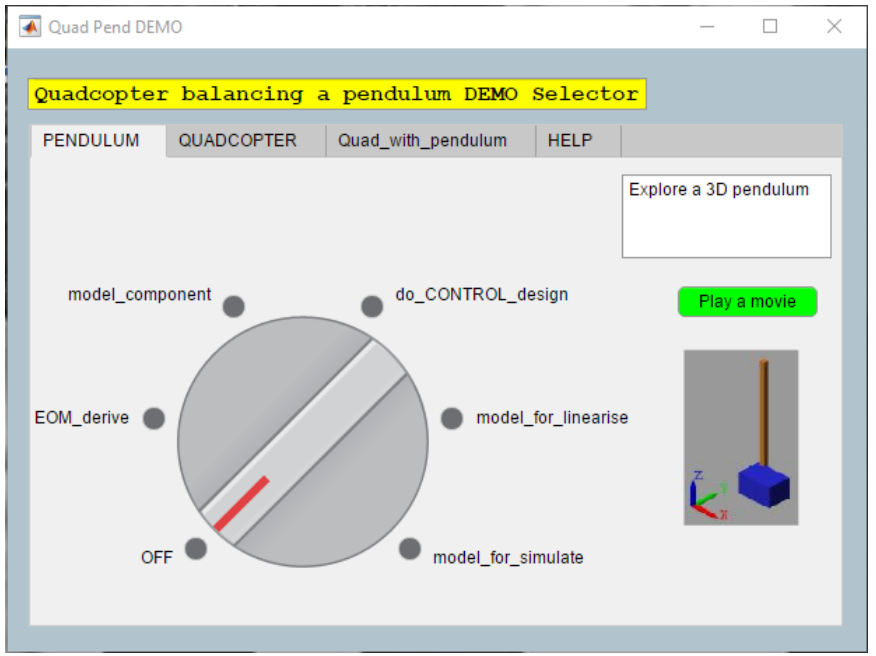
Launch the demo:

- Run the start-up function

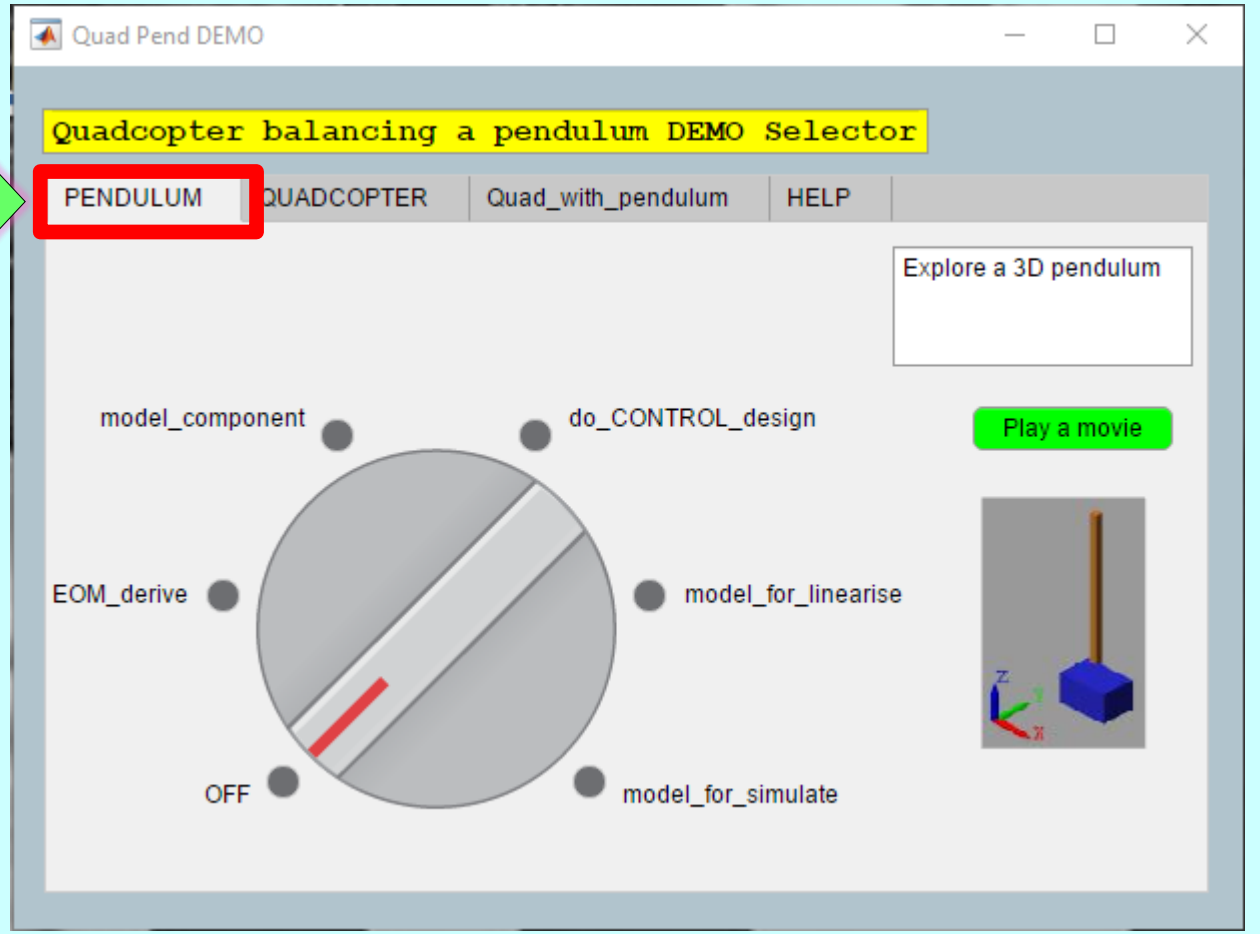
```
>> bh_startup_quad_and_pendulum
```

After running the start-up function the DEMO navigator APP will appear:





The Pendulum.

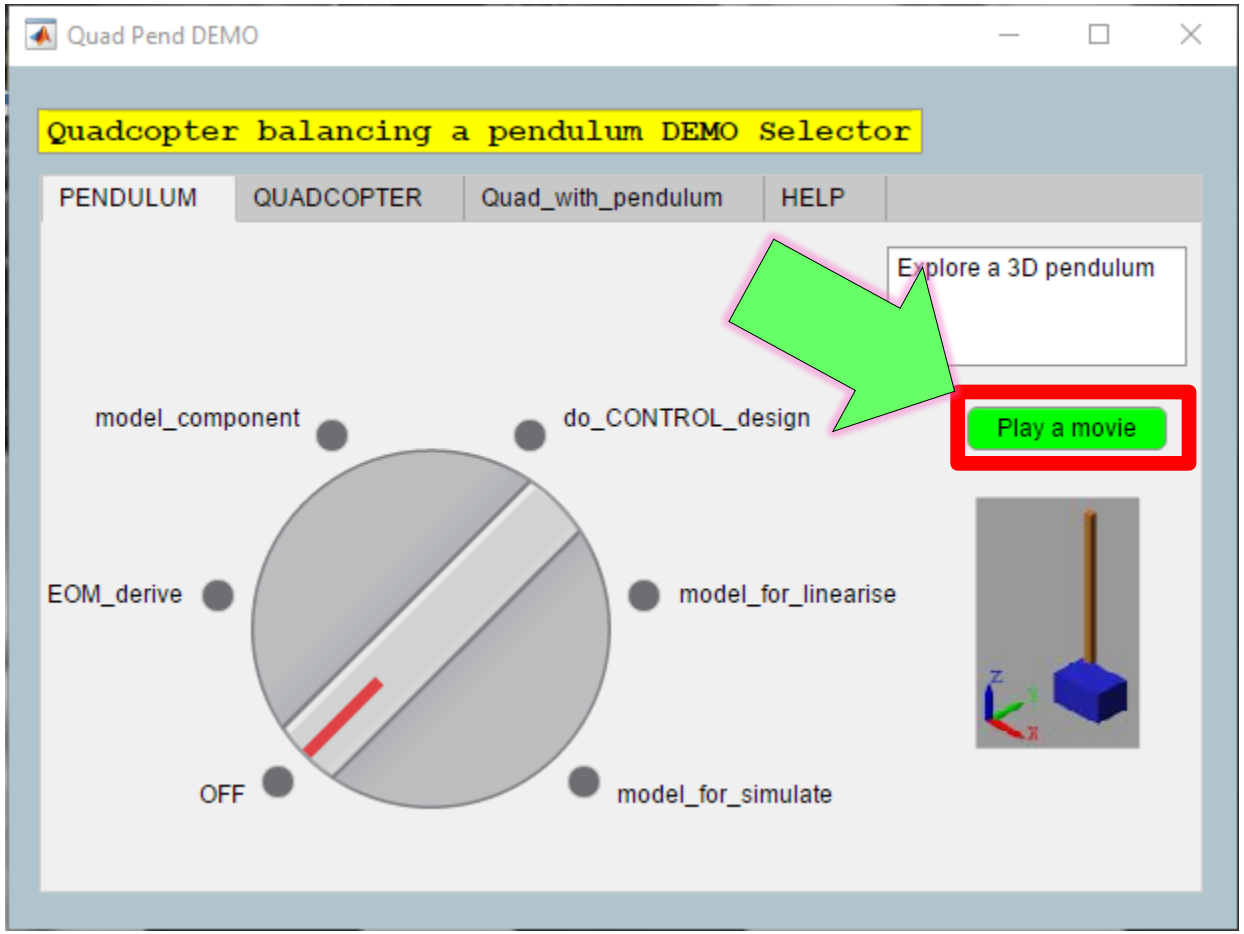


Pendulum demo: overview

- Derive equations of motion of a 3D pendulum
  - The pivot point base can move in X,Y,Z
- Use Symbolic toolbox to
  - Derive equations of motion
  - Create a matlabFunction block
- Design a control Law
- Simulate controlled system
  - Using hand derived model
  - Using a Simscape multibody model

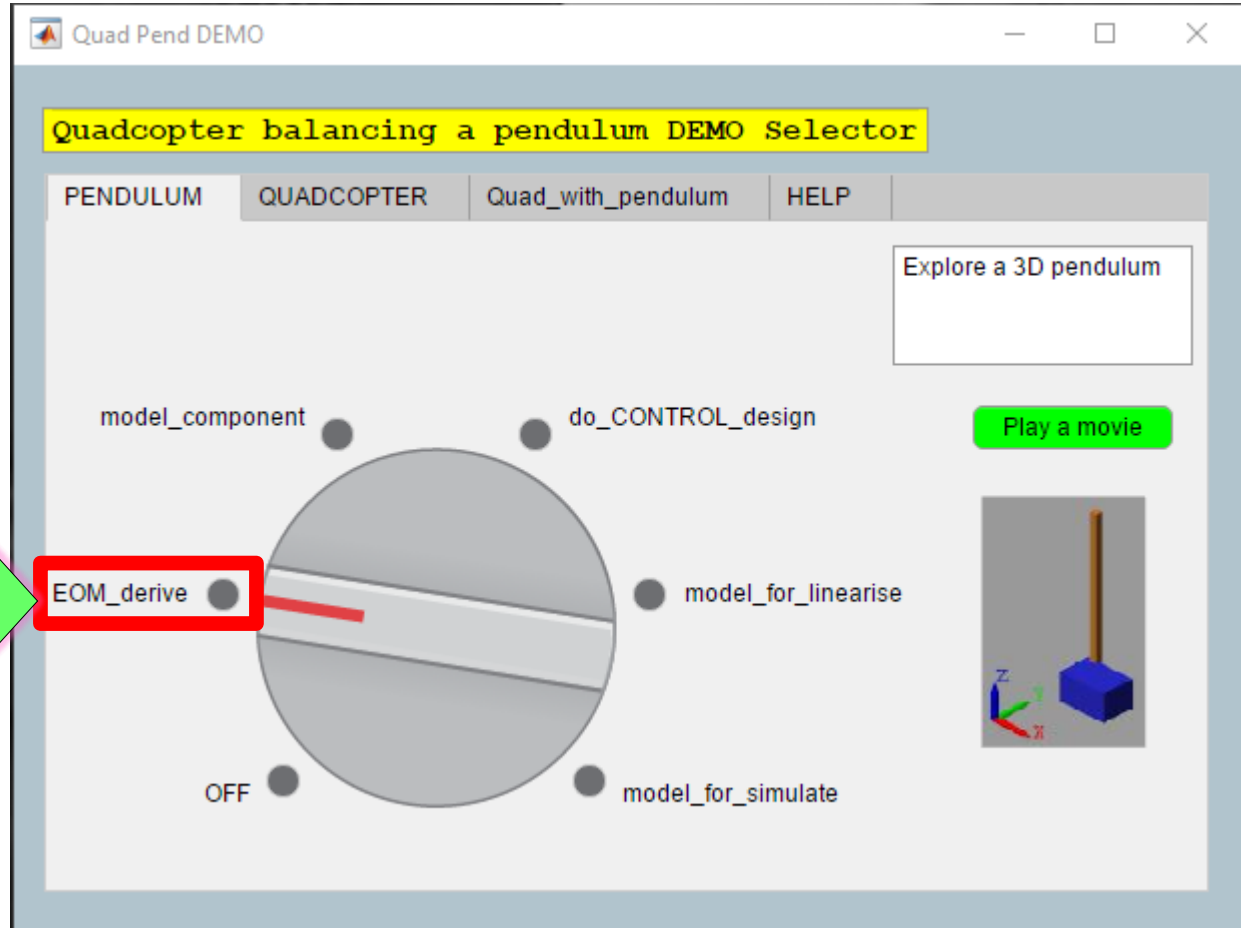
Comments on the PENDULUM demo: `Part 1 of 6`

- Opens the `implay()` video viewer (Image Proc tbox).
- Click the PLAY button in the video player …. and watch a short video on the finale model of the system



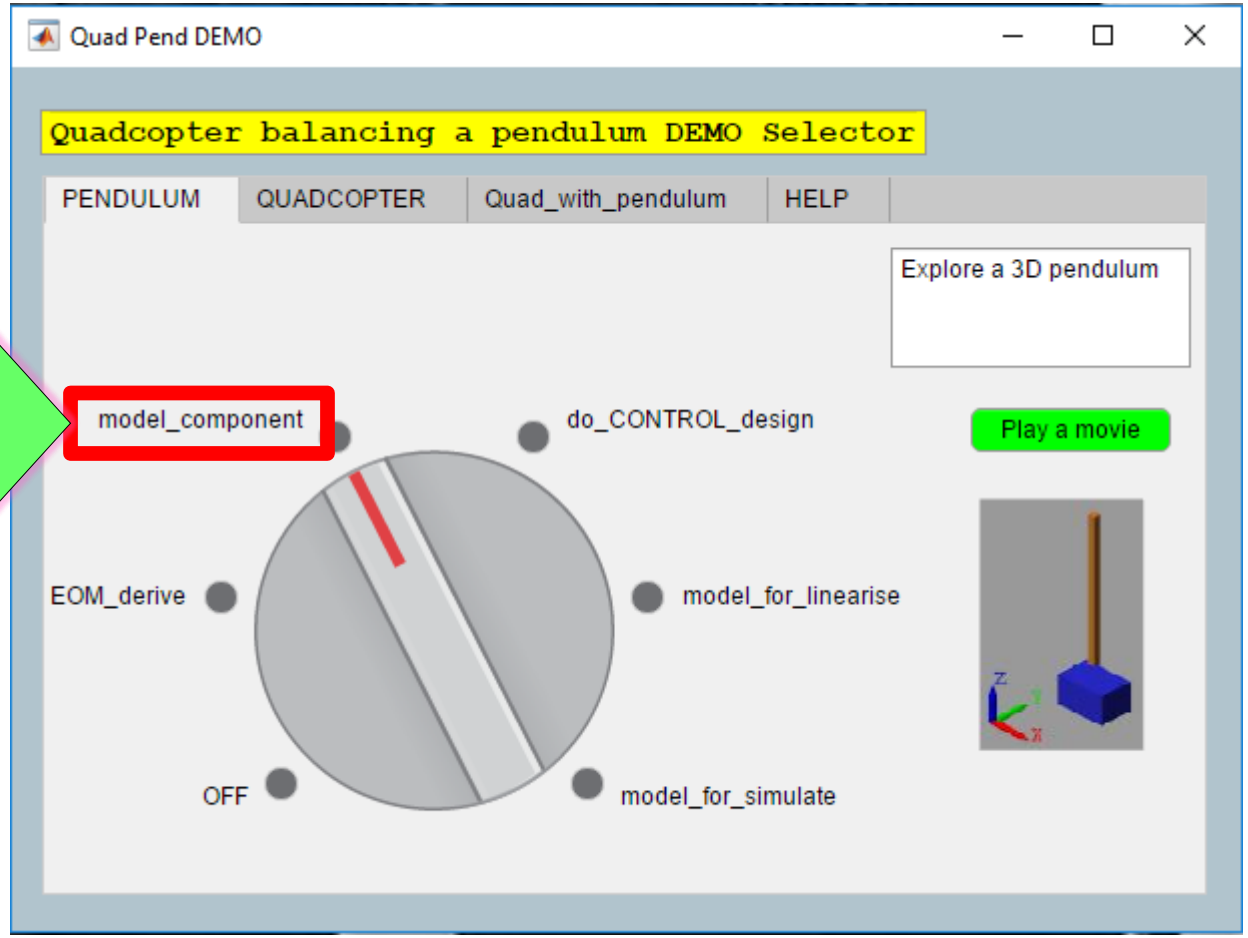
Comments on the PENDULUM demo: Part 2 of 6

- Opens a Live script.
- **YOU** manually run this script, to derive the Equations of motion for the pendulum.
- The Lagrangian technique is used.
- The output is a “yellow” MATLAB function block for Simulink – this contains the equations of motion



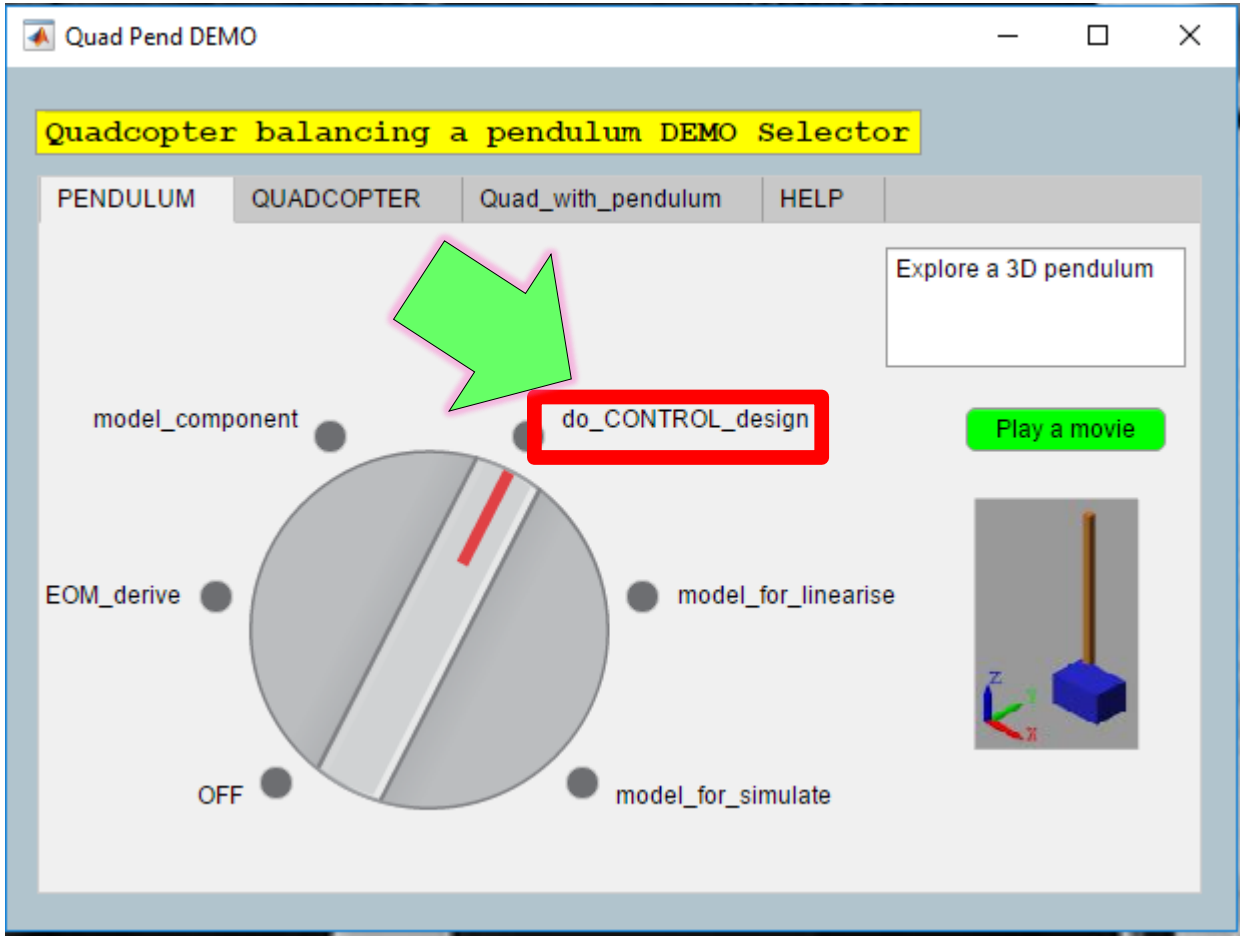
Comments on the PENDULUM demo: Part 3 of 6

- Opens a Simulink component model that contains our derived equations of motion.
- You **Do NOT run** this model.
- This model is referenced by other models
- So what do you do with it ?
  - Just have a look inside it.
  - Note the YELLOW block that contains our derived equations of motion.



Comments on the PENDULUM demo: Part 4 of 6

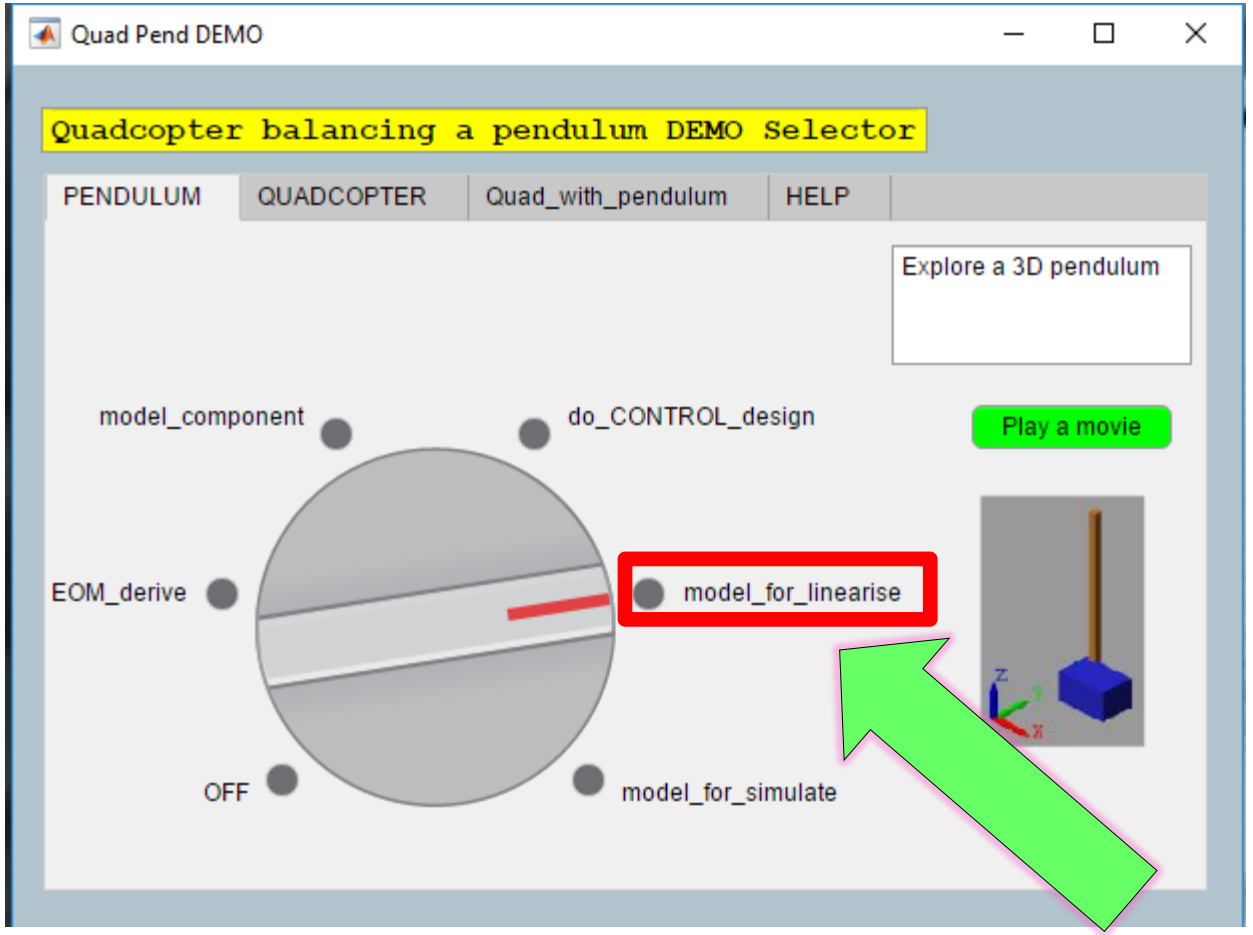
- Opens a Live script for doing a control design task.
- **YOU** manually run this script.
- The output of this script is a Control LAW “K”



Comments on the PENDULUM demo: Part 5 of 6

- Opens the Simulink model that was used for the linearization task of our Control design.

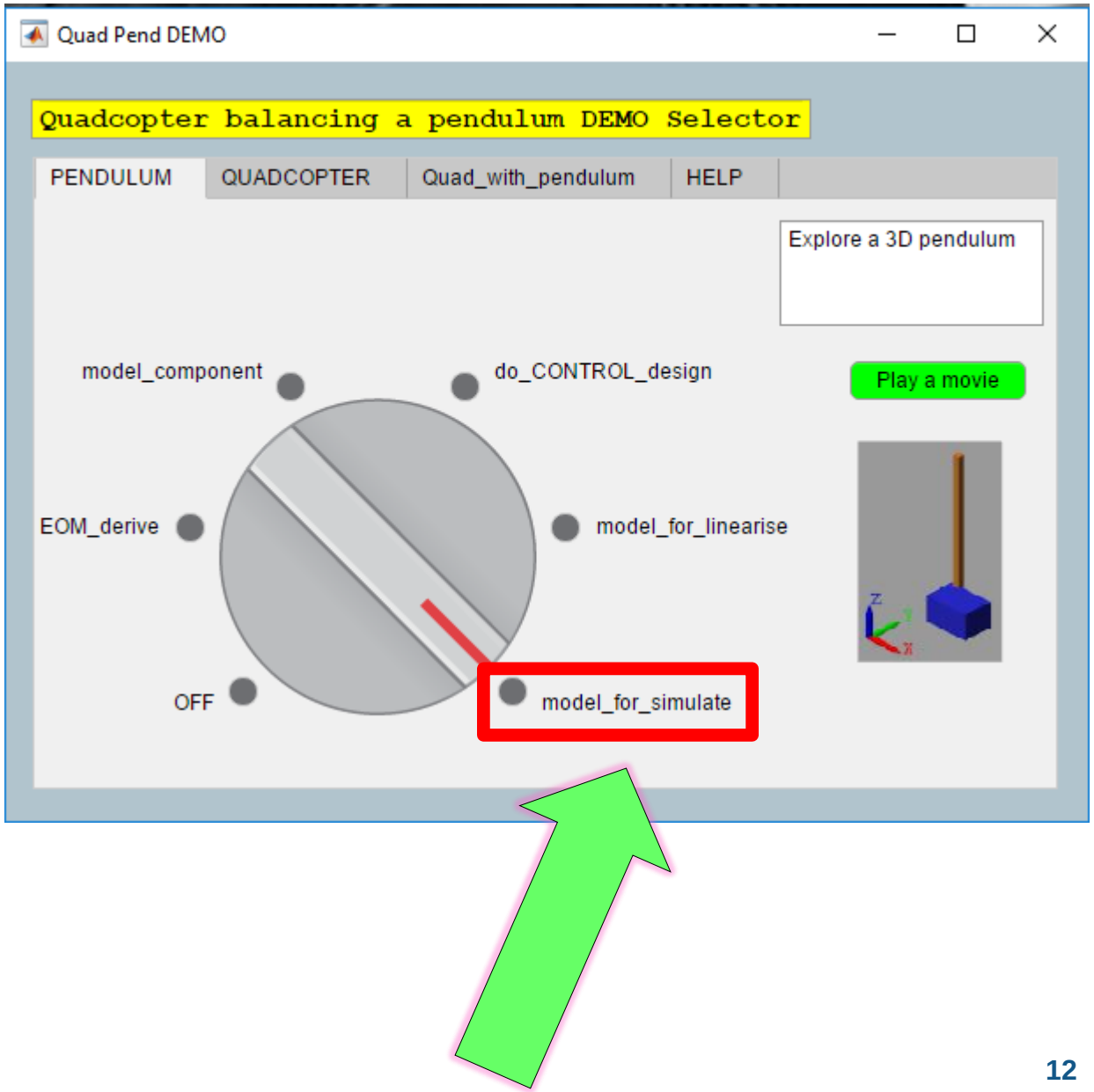
- So what do you do with it ?
  - You do NOT run this model
  - Just have a look inside it.



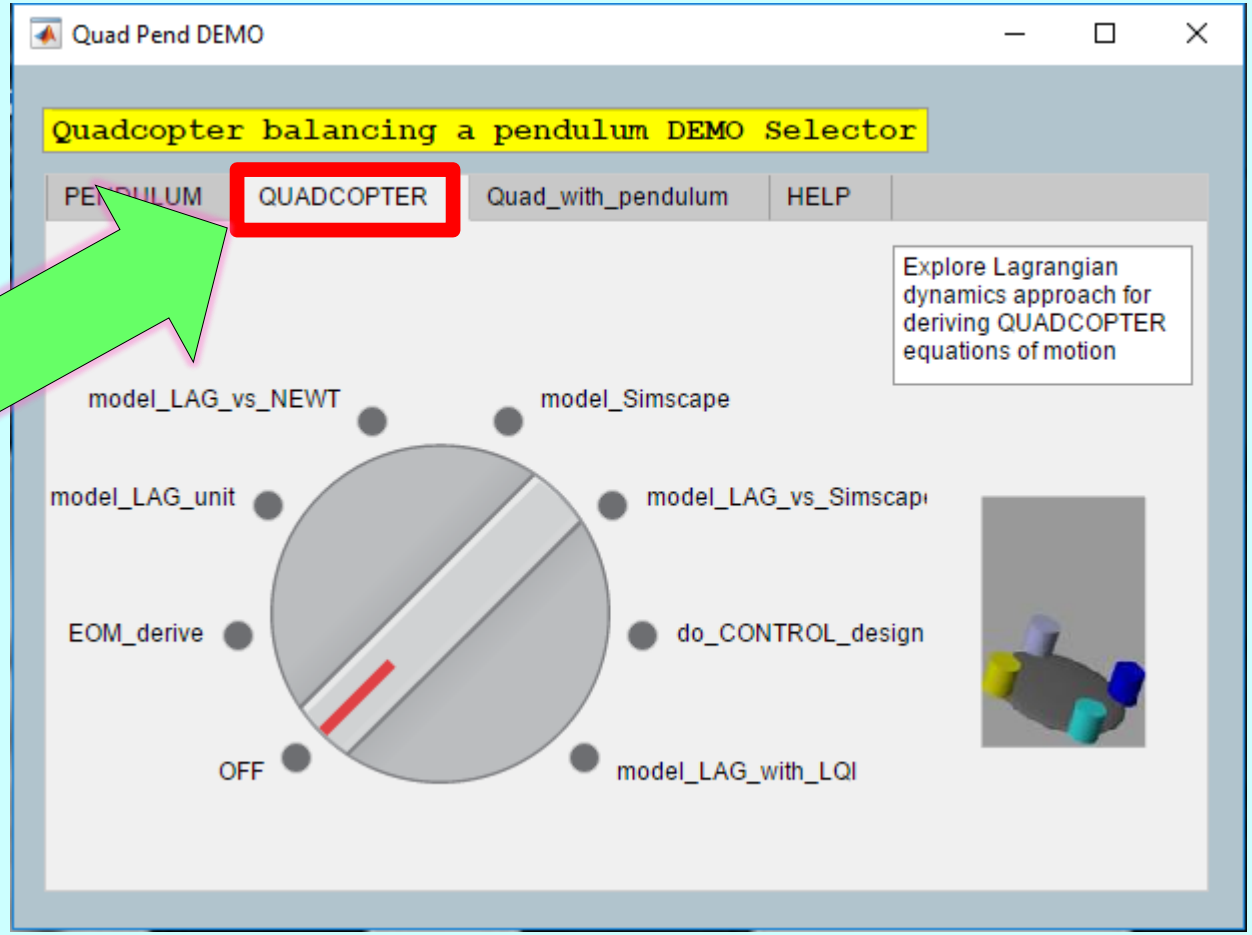
Comments on the PENDULUM demo: Part 6 of 6

- Opens a Simulink model that contains
  - Our hand derived model
  - A corresponding Simscape model
  - Our designed Control LAw

- So what do you do with it ?
  - You **Run** it.
  - Observe that the hand derived model produces the same outputs as the Simscape model.



The Quadcopter.

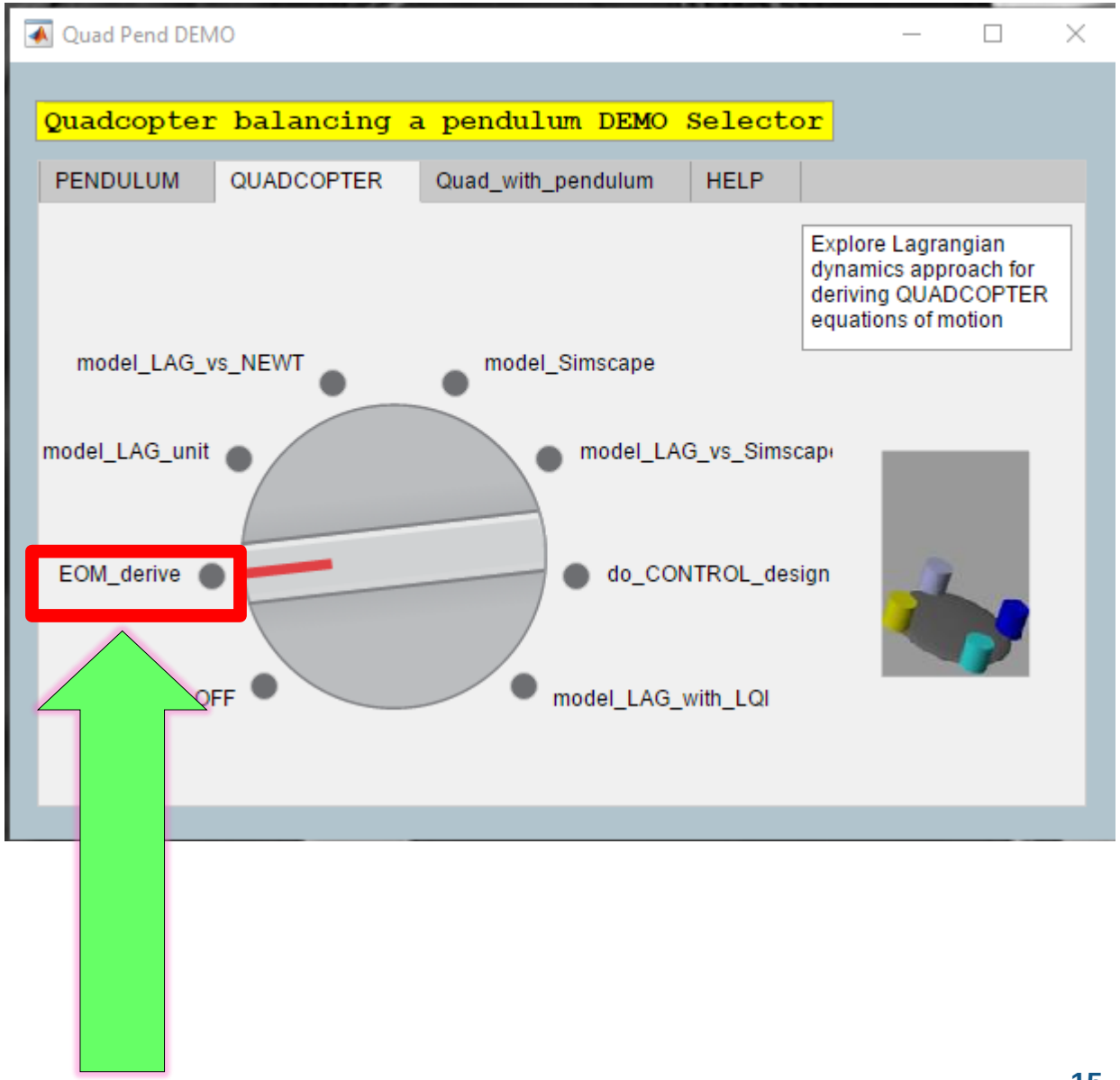


Quadcopter demo: overview

- Derive equations of motion of a 6-dof quadcopter
  - Include spinning propellers
- Use Symbolic toolbox to
  - Derive equations of motion
- Create a model using Simscape
- Compare Hand derived model against Simscape model
  - Both models use the exact same multi cascade control law
- Design an alternate control law using the LQI technique
  - Simulate controlled quadcopter using the LQI controller

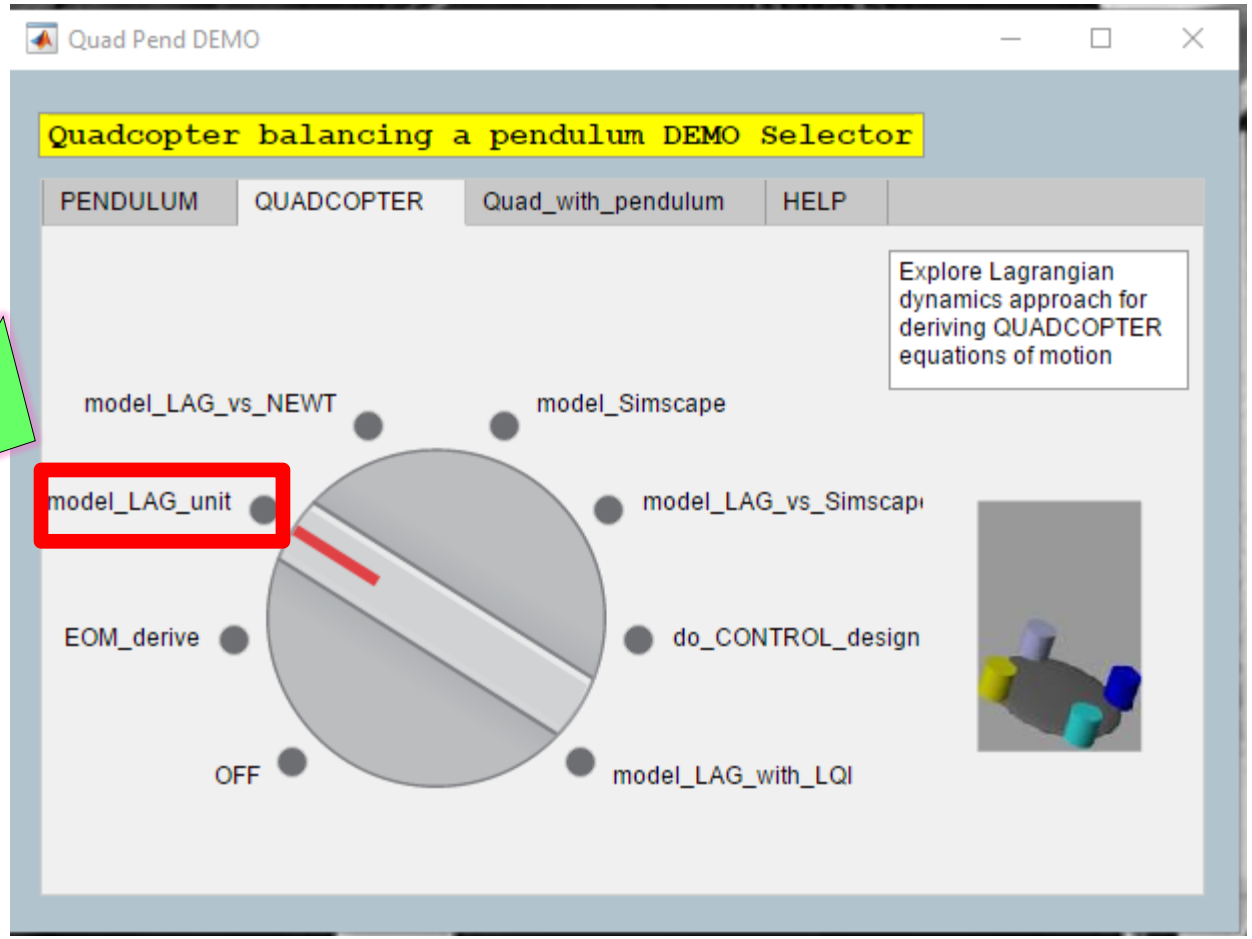
Comments on the Quadcopter demo: Part 1 of 7

- Opens a Live script.
- **YOU** manually run this script, to derive the Equations of motion for the QUADCOPTER.
- The Lagrangian technique is used.
- The output is a “yellow” MATLAB function block for Simulink – this contains the equations of motion



Comments on the Quadcopter demo: Part 2 of 7

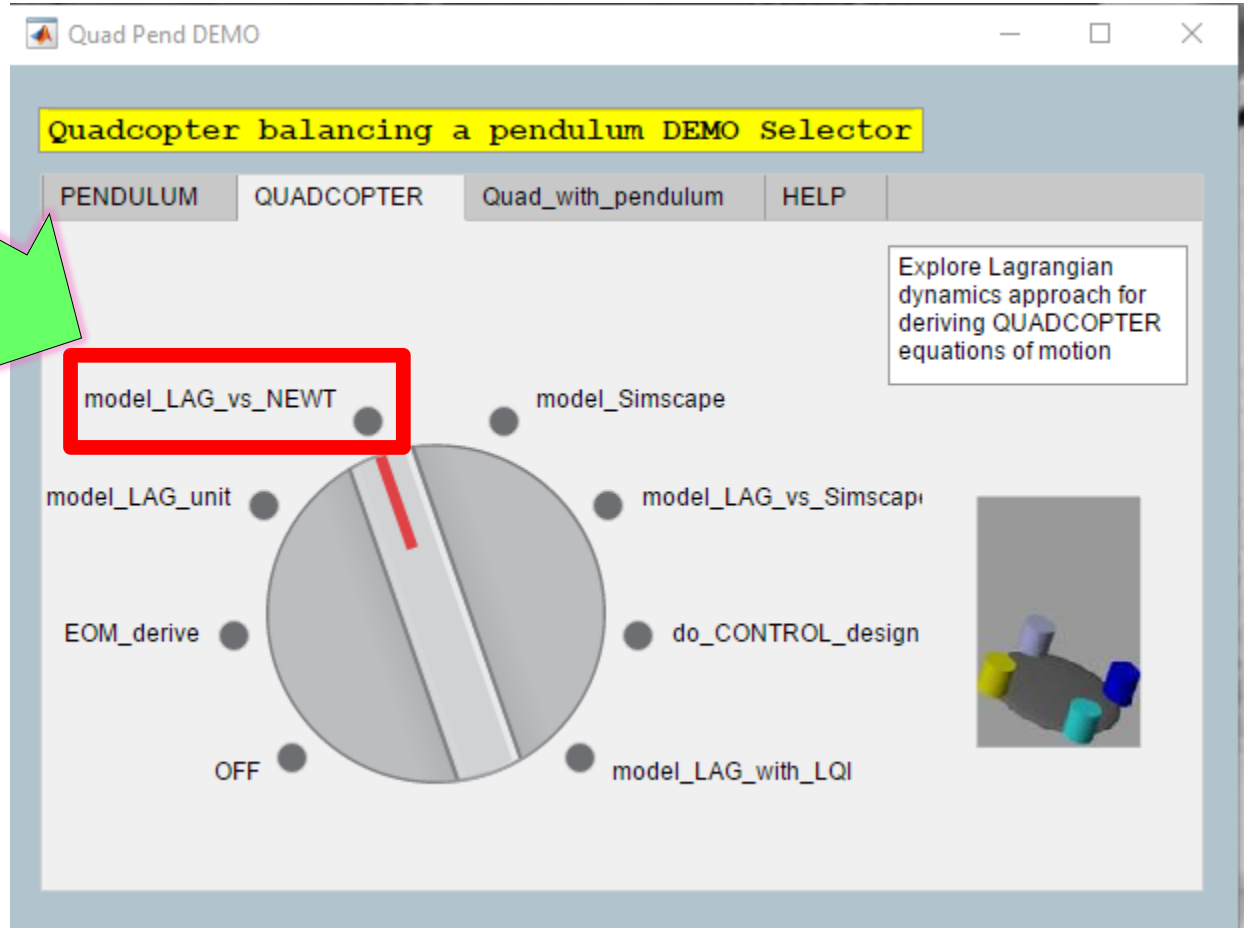
- Opens a Simulink component model that contains our derived equations of motion.
- You **Do NOT run** this model.
- This model is referenced by other models
- So what do you do with it ?
  - Just have a look inside it.
  - Note the YELLOW block that contains our derived equations of motion.



Comments on the Quadcopter demo: Part 3 of 7

- Opens a Simulink model that contains
  - Our hand derived model (Lagrange)
  - A corresponding model derived using NEWTON's laws

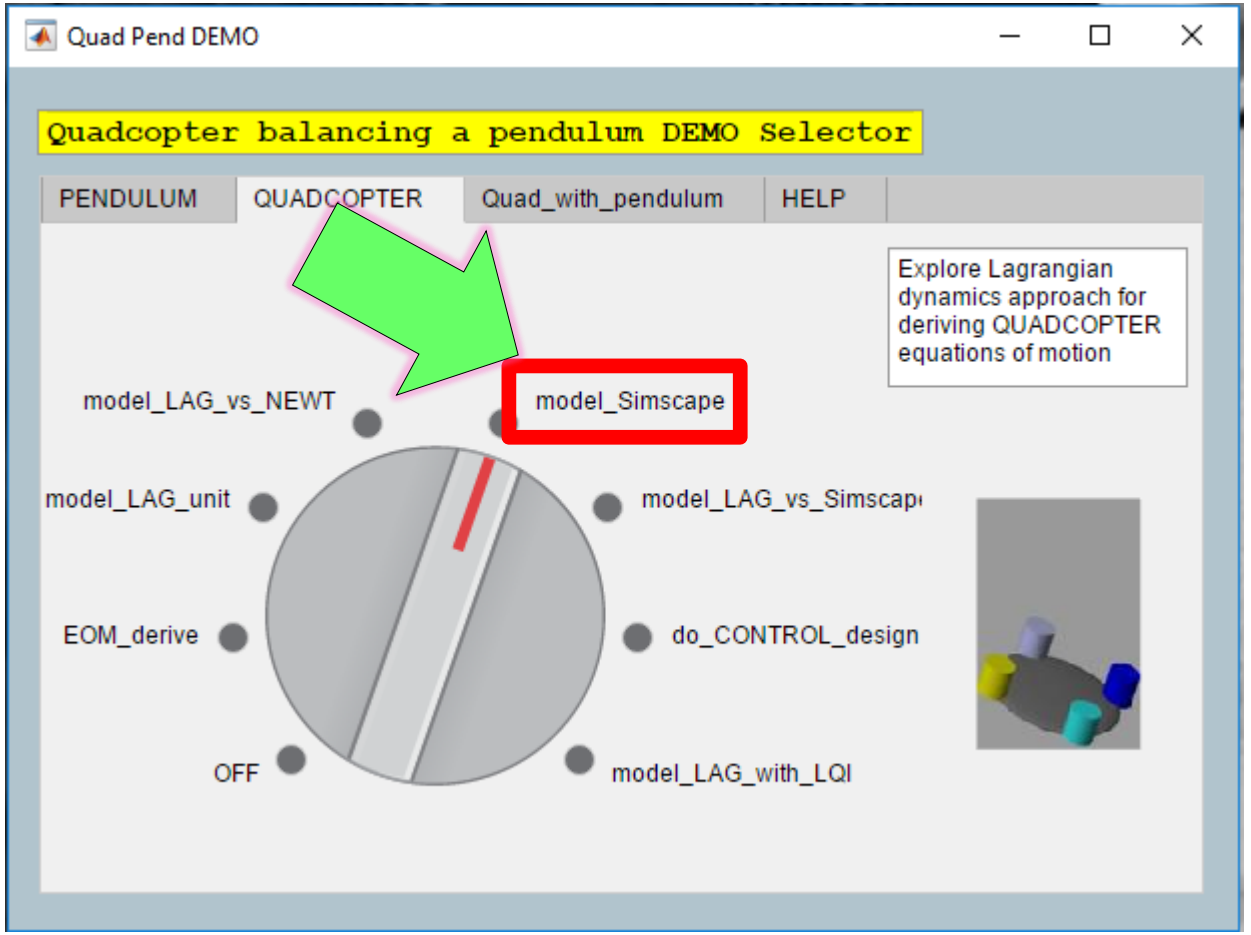
- So what do you do with it ?
  - You **Run** it.
  - Observe that the Lagrangian model output is very similar to the NEWTON derived model



Comments on the Quadcopter demo: Part 4 of 7

- Opens a Simulink model that contains
  - A Simscape multibody version of the Quadcopter

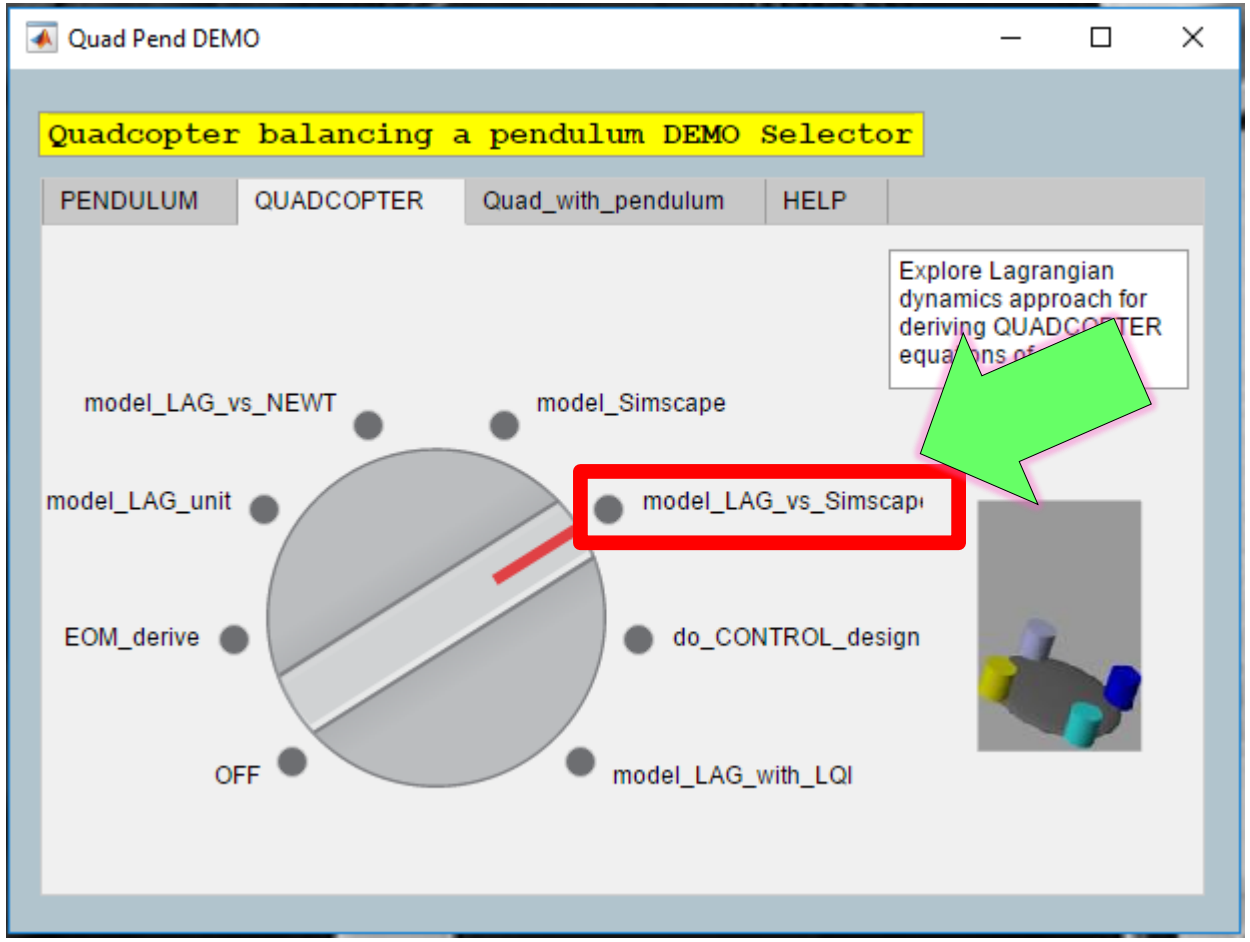
- So what do you do with it ?
  - You **Run** it.



Comments on the Quadcopter demo: Part 5 of 7

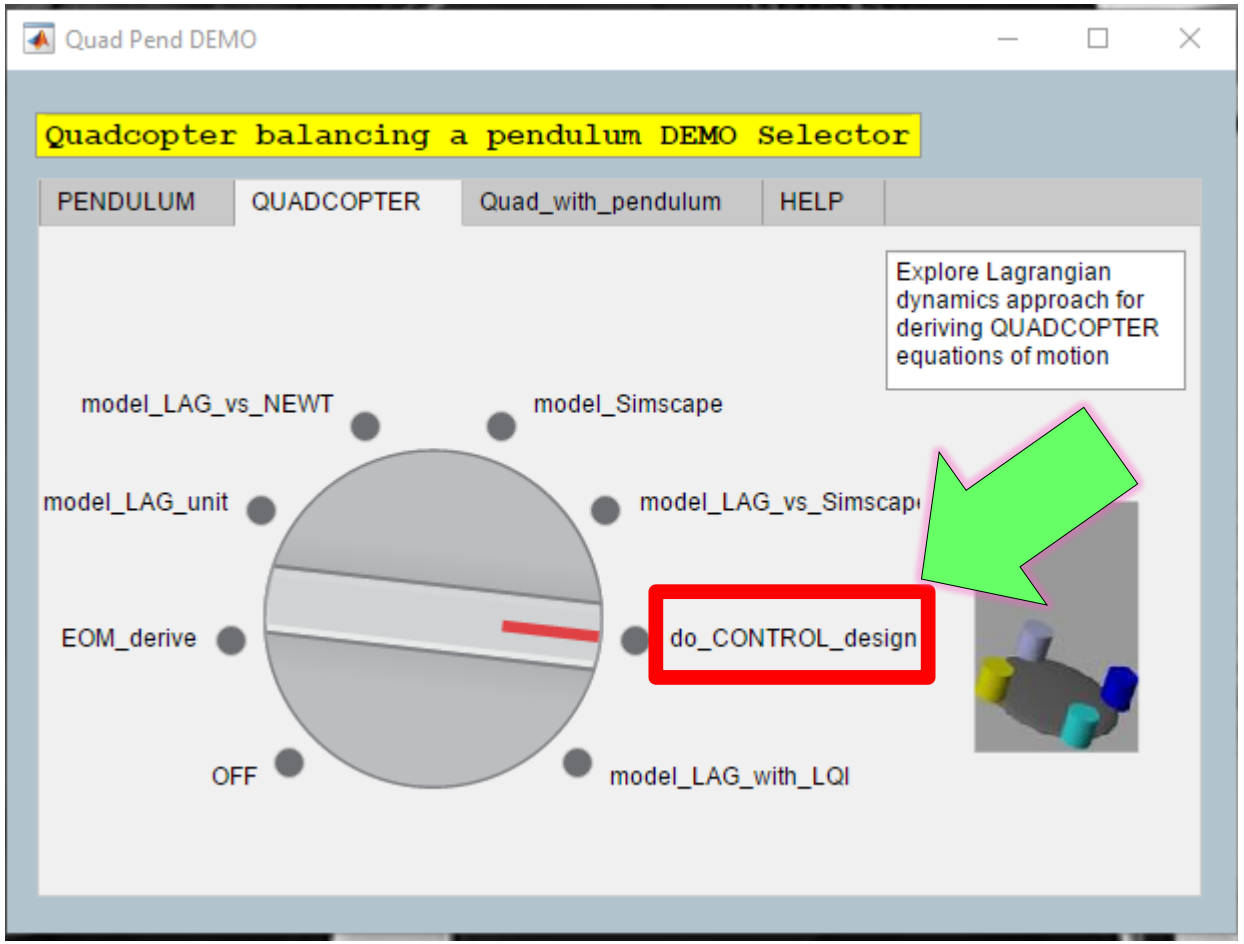
- Opens a Simulink model that contains
  - Our Lagrangian derived model
  - Our Simscape multibody version of the Quadcopter

- So what do you do with it ?
  - You **Run** it.
  - Observe that the Lagrangian model output is very similar to the Simscape model



Comments on the Quadcopter demo: Part 6 of 7

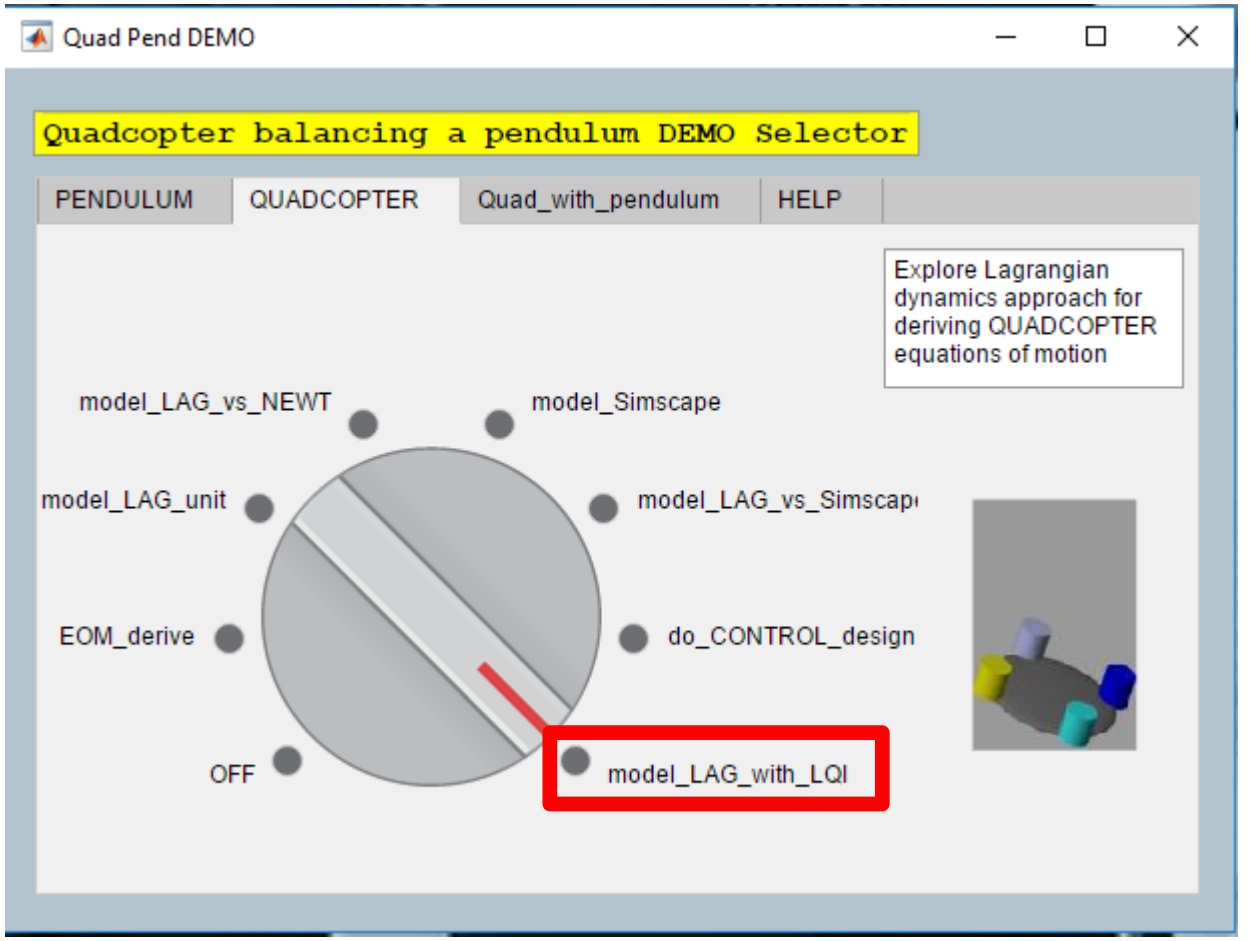
- Opens a Live script for doing a control design task.
  - Uses the LQI technique
  - Uses our hand derived plant model
- **YOU** manually run this script.
- The output of this script is a Control LAW “K”



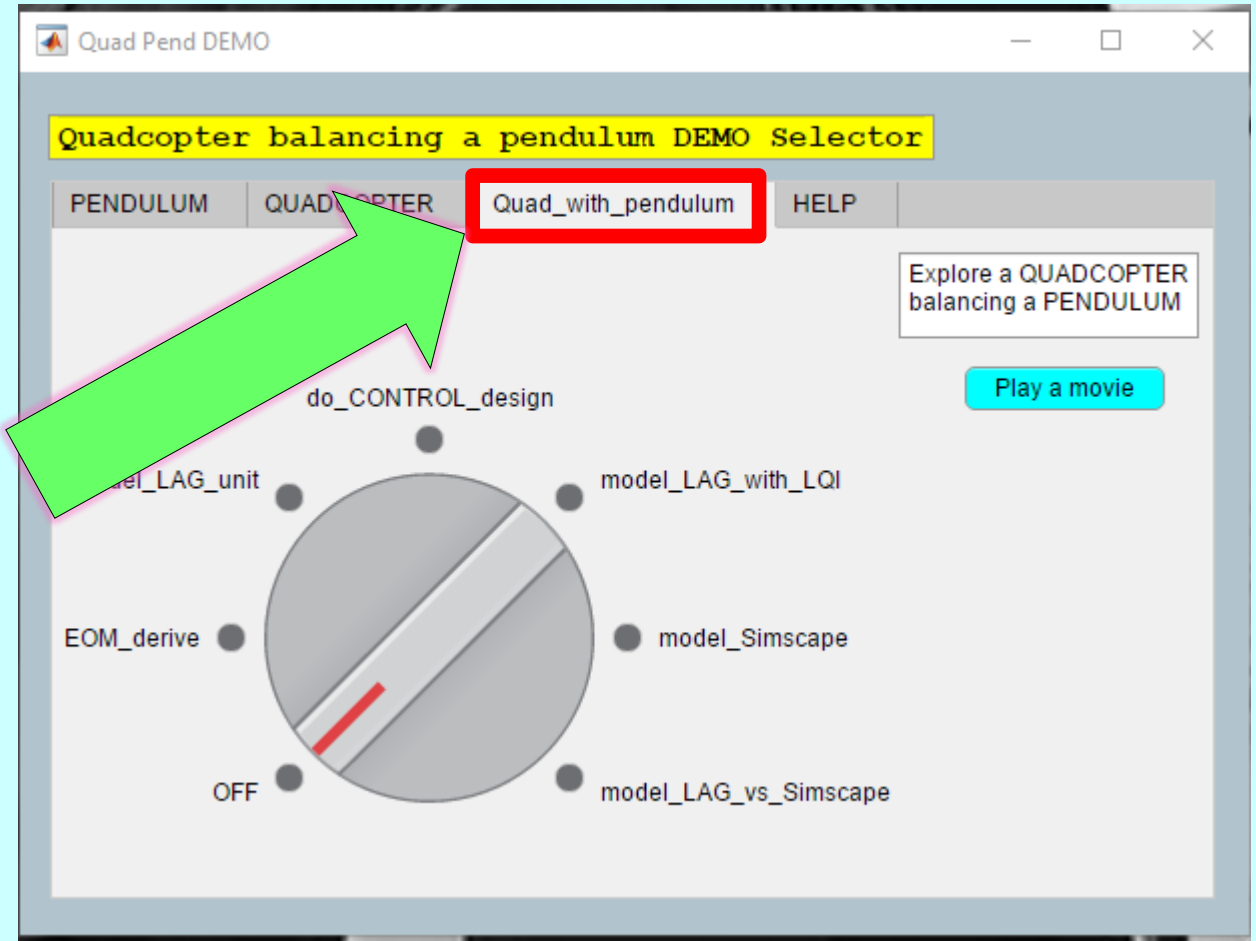
Comments on the Quadcopter demo: Part 7 of 7

- Opens a Simulink model that contains
  - Our hand derived model
  - Our designed LQI Control LAw

- So what do you do with it ?
  - You **Run** it.



The Quadcopter Balancing The pendulum

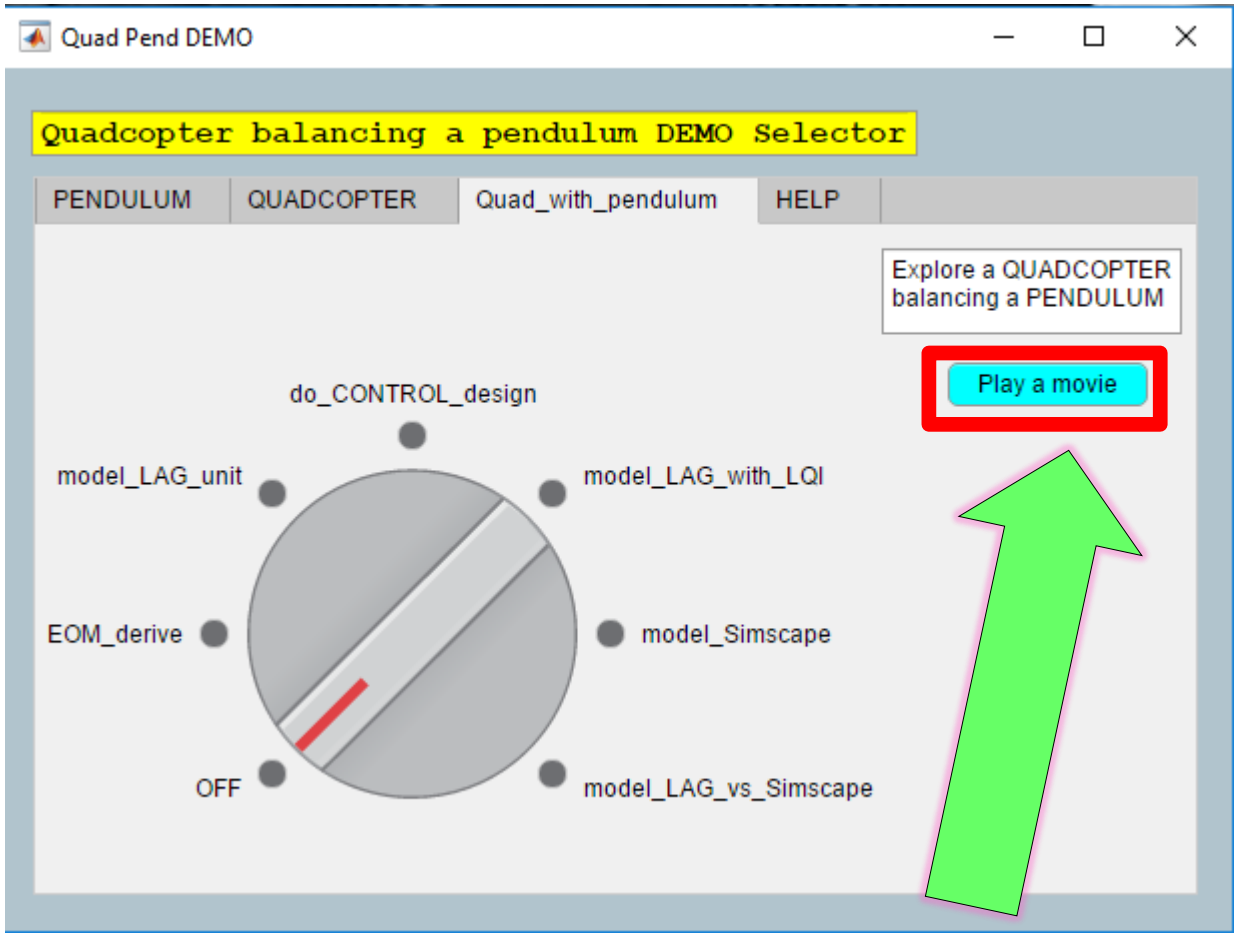


Quadcopter balancing pendulum demo: overview

- Derive equations of motion of a 6-dof quadcopter with a pendulum
  - Include spinning propellers
- Use Symbolic toolbox to
  - Derive equations of motion
- Use derived plant model to design control law using the LQI technique
  - Simulate controlled quadcopter using the LQI controller
- Create a model using Simscape
- Compare Hand derived model against Simscape model
  - Both models use the exact same LQI control law

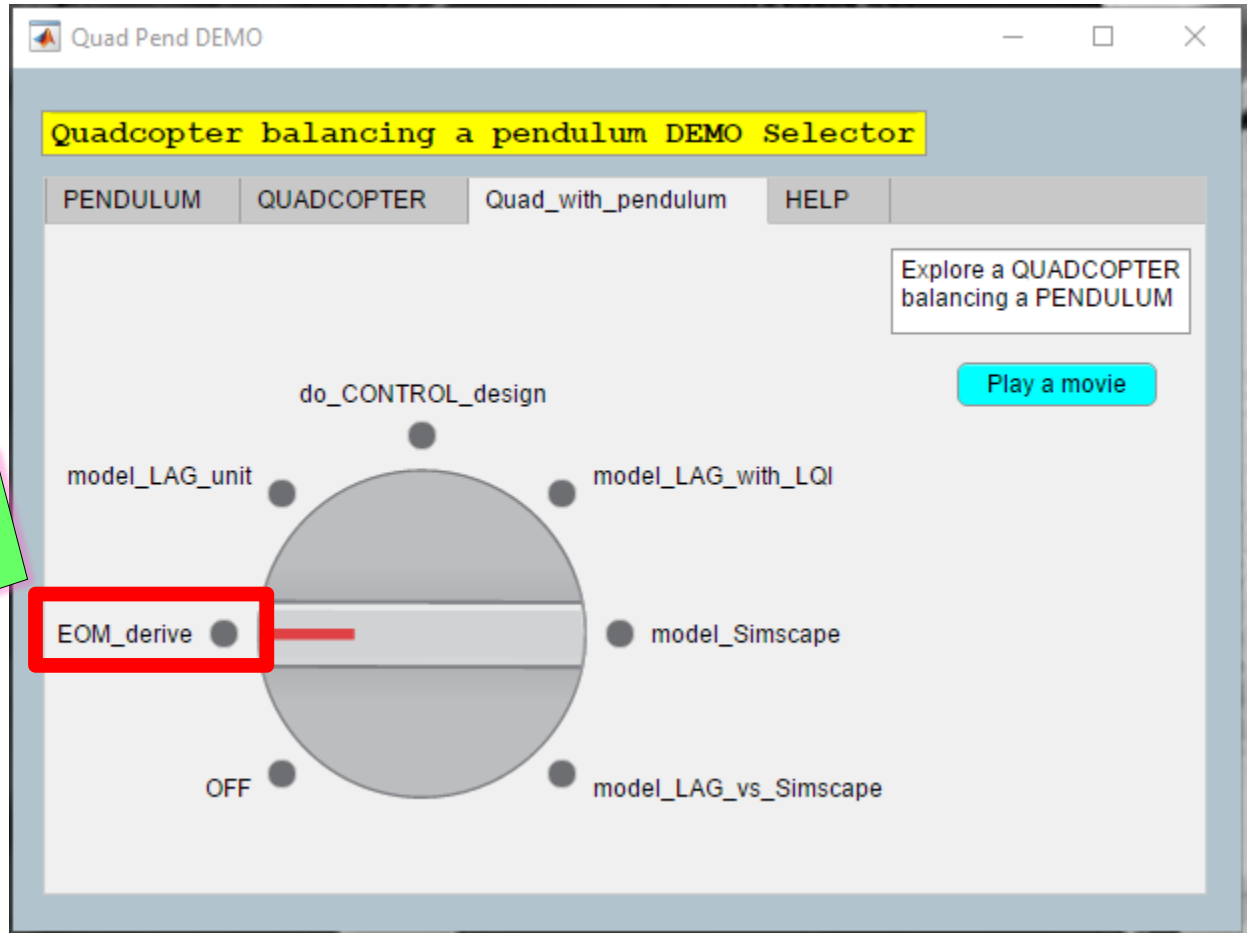
Comments on the **Quadcopter balancing a pendulum** demo: `Part 1 of 7`

- Opens the `implay()` video viewer (Image Proc tbox).
- Click the PLAY button in the video player …. and watch a short video on the finale model of the system



Comments on the **Quadcopter balancing a pendulum** demo: Part 2 of 7

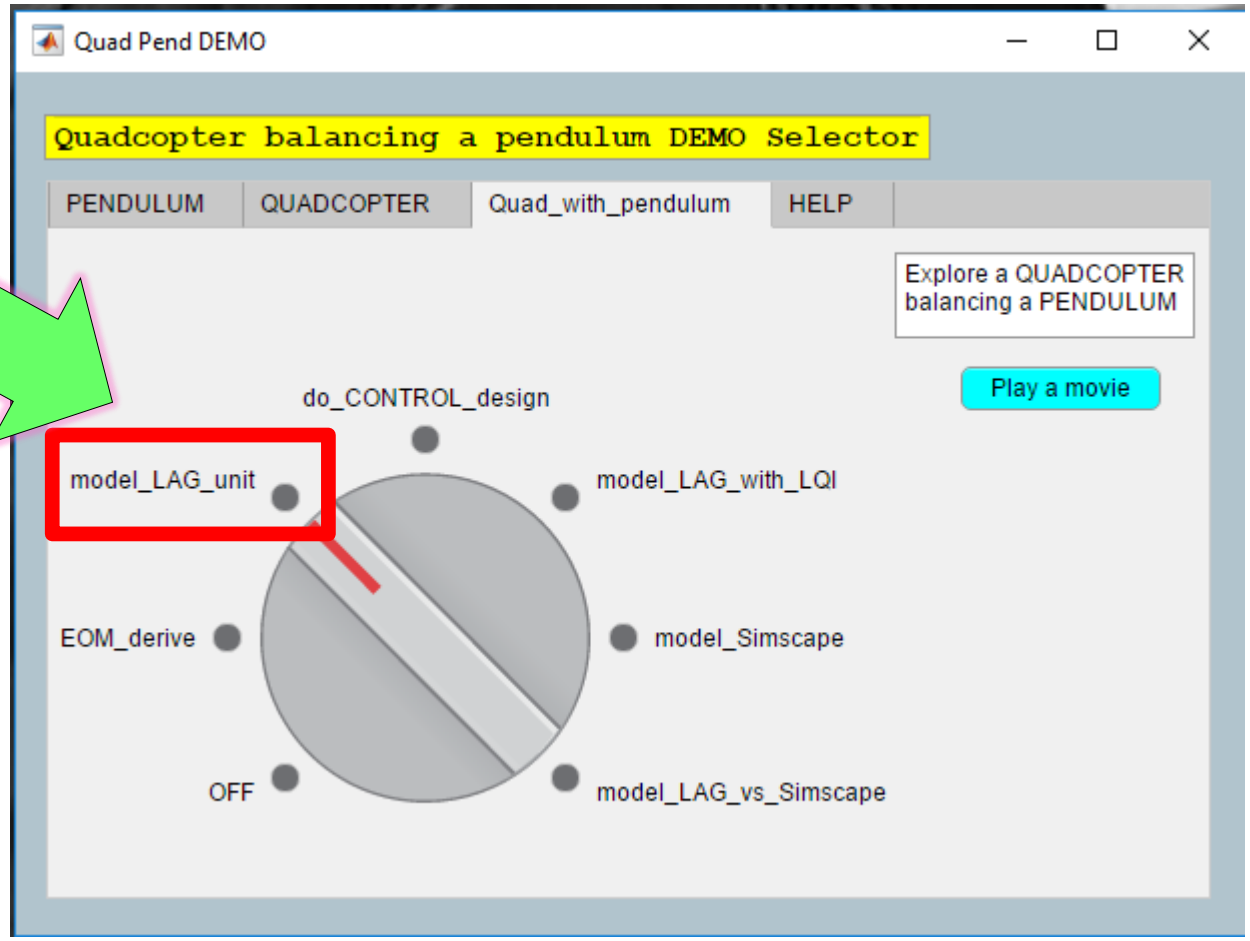
- Opens a Live script.
- **YOU** manually run this script, to derive the Equations of motion for the QUADCOPTER.
- The Lagrangian technique is used.
- The output is a “yellow” MATLAB function block for Simulink – this contains the equations of motion



- **ATTENTION:**
  - **The live script tales 10 minutes to run on a Lenovo P50 laptop**
  - **So it’s probably not sensible to try and run it in front of a professor.**
  - **The outputs of this script (ie: a yellow Simulink block) are already to go in a model on the next slide !**

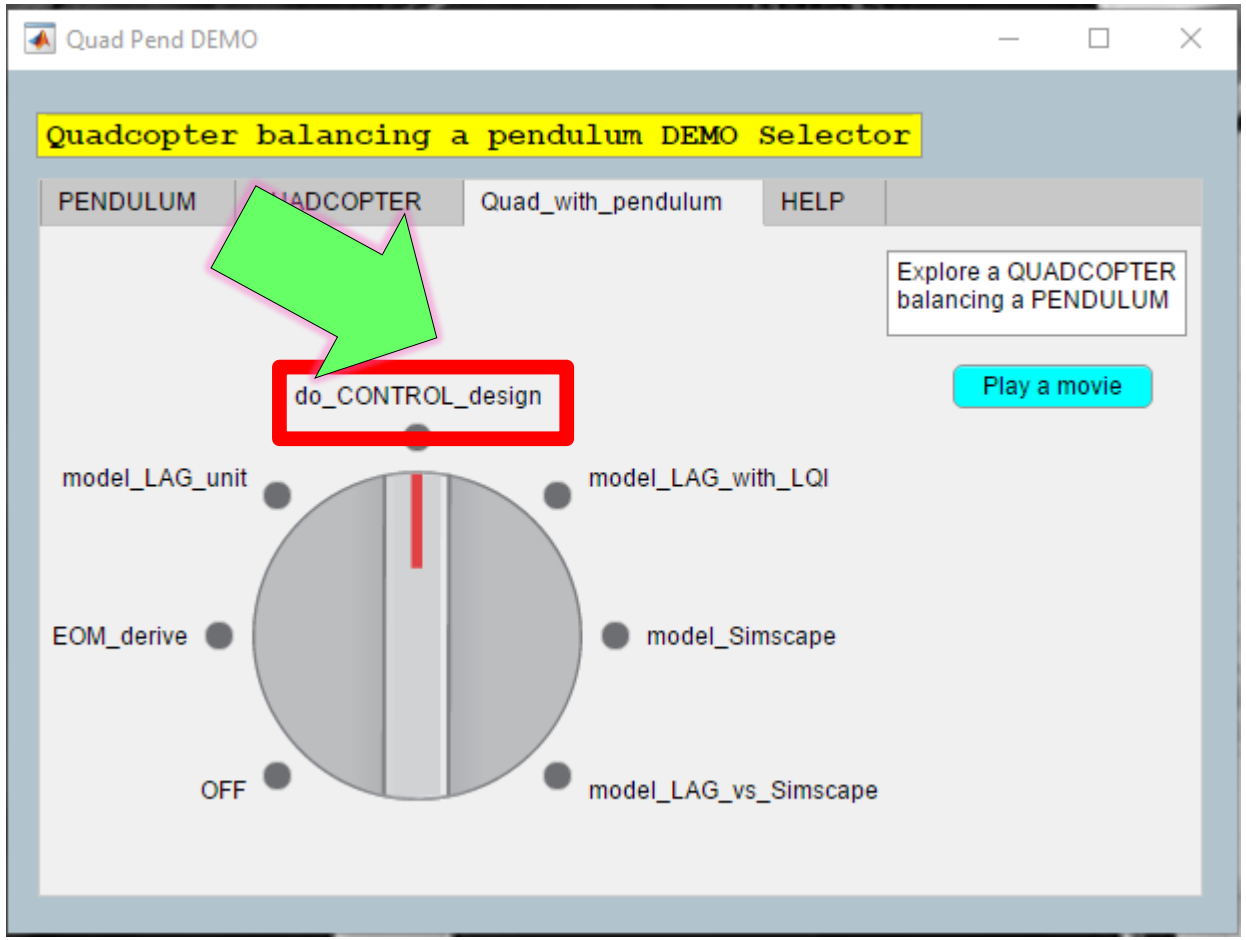
Comments on the **Quadcopter balancing a pendulum** demo: Part 3 of 7

- Opens a Simulink component model that contains our derived equations of motion.
- You **Do NOT run** this model.
- This model is referenced by other models
- So what do you do with it ?
  - Just have a look inside it.
  - It contains the YELLOW block that would have been created had you allowed the script on the previous slide to run (for 10 minutes)
  - The yellow MATLAB Function block contains our derived equations of motion



Comments on the **Quadcopter balancing a pendulum** demo: Part 4 of 7

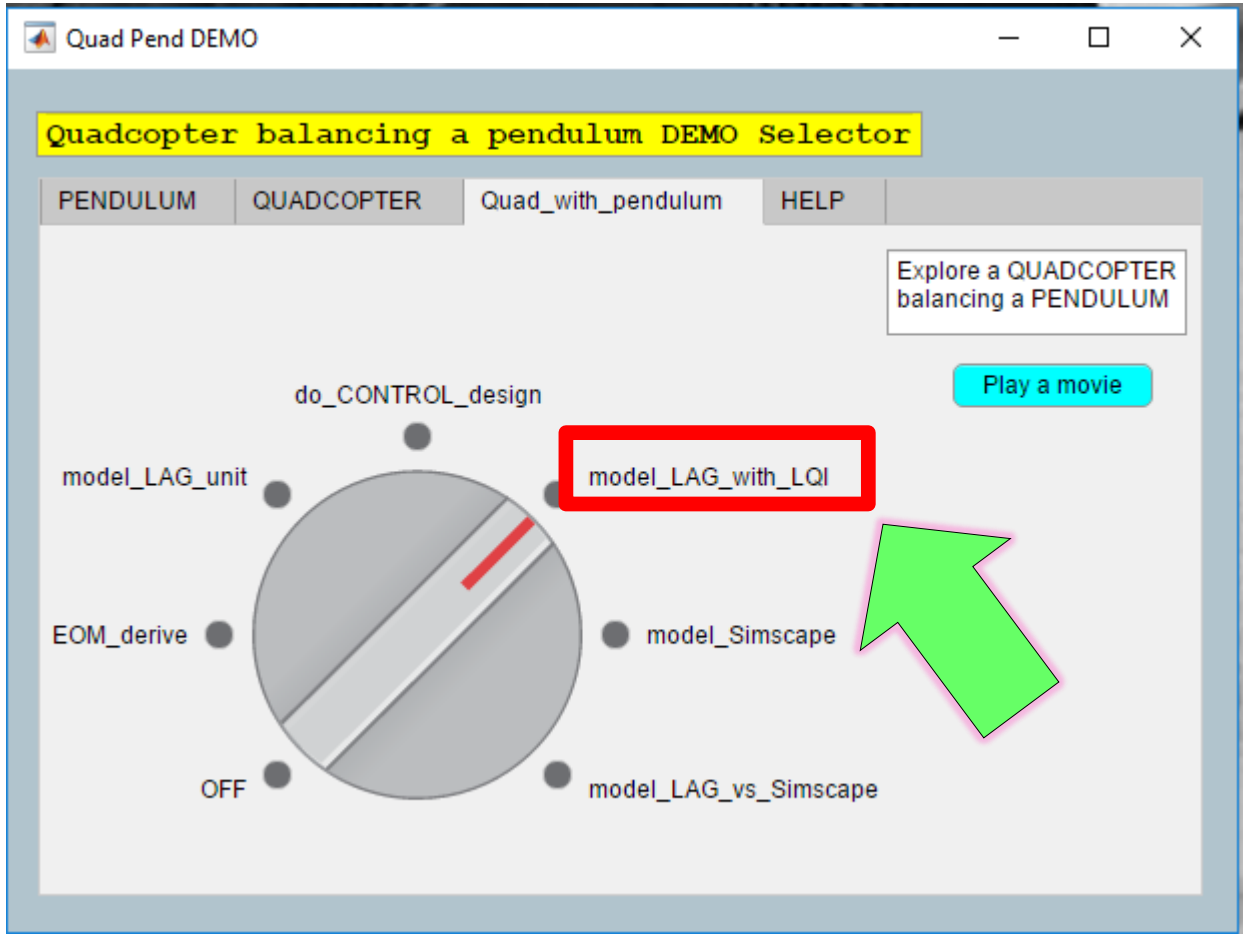
- Opens a Live script for doing a control design task.
  - Uses the LQI technique
  - Uses our hand derived plant model
- **YOU** manually run this script.
- The output of this script is a Control LAW “K”



Comments on the **Quadcopter balancing a pendulum** demo: Part 5 of 7

- Opens a Simulink model that contains
  - Our hand derived model
  - Our designed LQI Control LAw

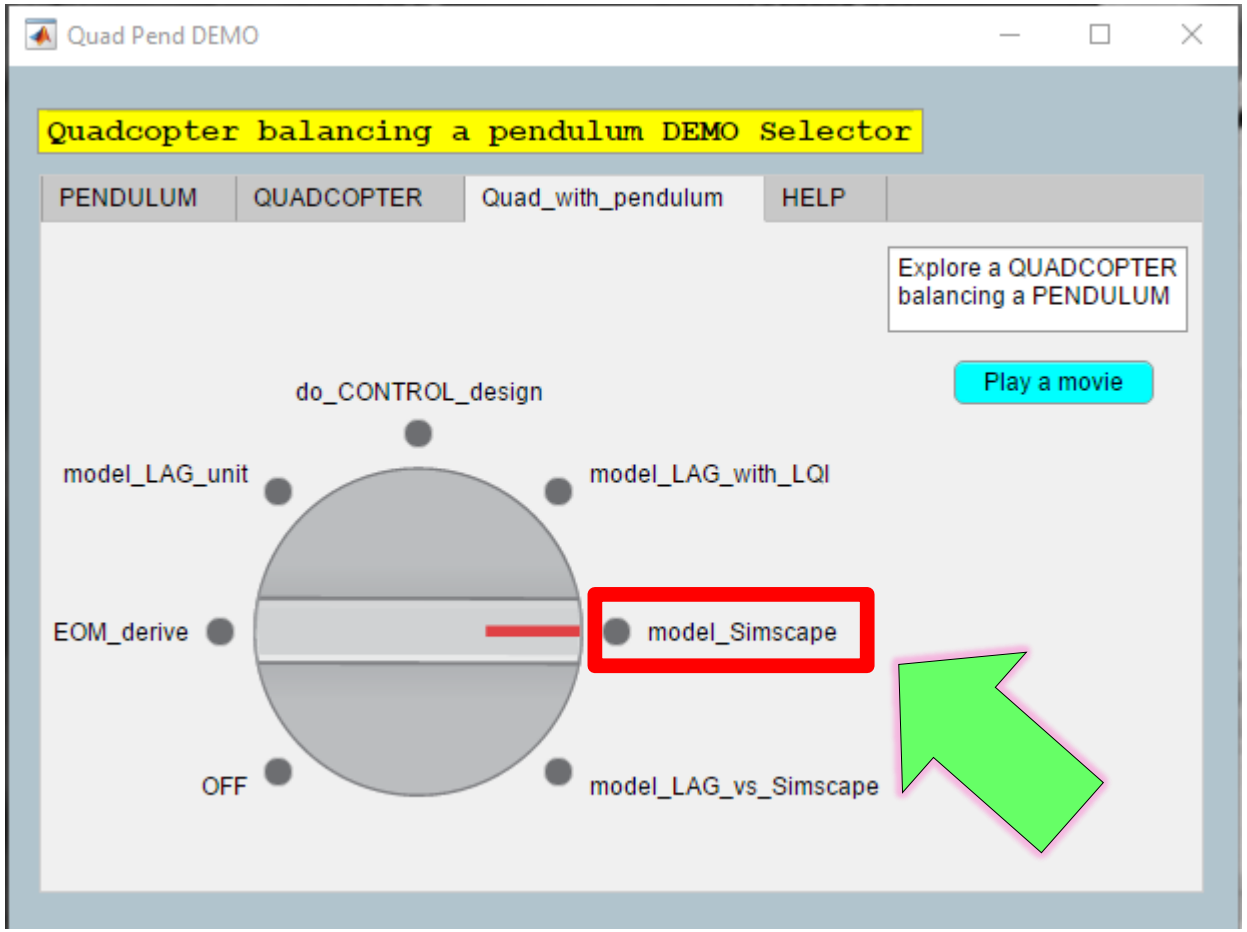
- So what do you do with it ?
  - You **Run** it.



Comments on the **Quadcopter balancing a pendulum** demo: Part 6 of 7

- Opens a Simulink model that contains
  - A Simscape multibody version of the Quadcopter balancing the pendulum
  - Uses the identical LQI control law used on the previous slide.

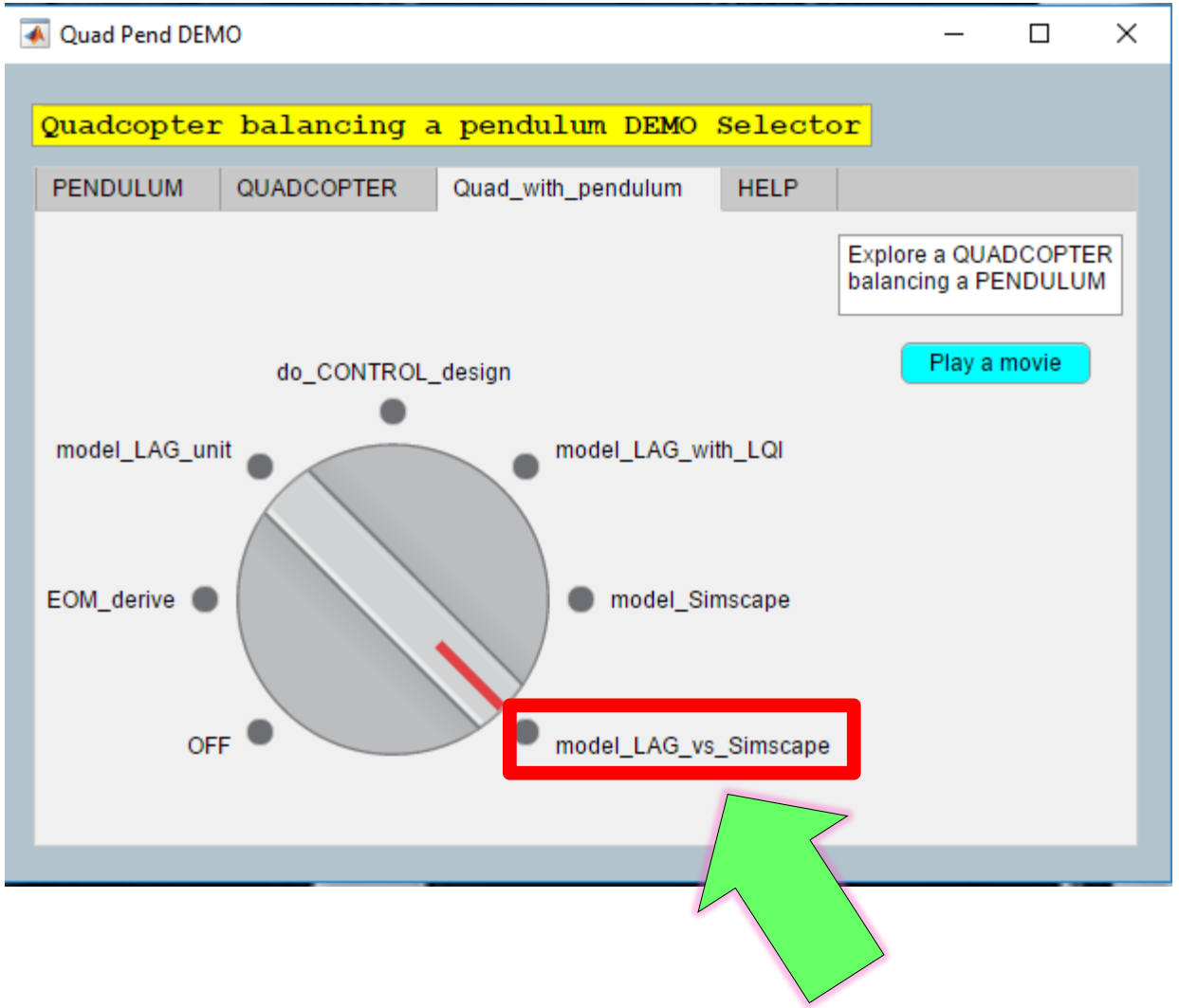
- So what do you do with it ?
  - You **Run** it.



Comments on the **Quadcopter balancing a pendulum** demo: Part 7 of 7

- Opens a Simulink model that contains
  - Our hand derived model
  - The corresponding Simscape model
  - Our designed LQI Control aw

- So what do you do with it ?
  - You **Run** it.
  - Observe that the hand derived model produces very similar outputs as the Simscape model.



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