2017

Drone Landing Gear Project

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ME 421

12/8/2017

Subject: Final Project Documentation

Class: ME 421

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Date: December 8, 2017

Final project documentation as asked for by Dr. Beyerlein. This paper will outline findings I made while designing a retracting landing gear system for a quadcopter drone.

Project Statement and Deliverables

Design retracting landing gear for a small quadcopter drone:

- The system should minimize weight, cost, and power consumption to maximize battery life
- Torque must be maximized when the landing gear is out and minimized when in
- The number of components should be minimized
- The drone as a whole does not need to be complete, but a mechanical system for the landing gear should be designed or conceptualized.

Kinematic Studies

Kinematic studies seek to prove or disprove that a mechanical concept is worth either use or further analysis. They are conceptual with no values applied or found. Two motion studies were performed and evaluated based on these criteria:

- Torque maximization
- Component simplicity
- Usage of space

Kinematic studies were performed in CATIA by creating assemblies and moving components with respect to their constraints. This demonstrated where torque was weak or strong. The dimensions and locations of components were adjusted to help prove whether a design is viable or not.

Kinematic Study 1:

Kinematic study 1 evaluated the use of rotatory servo motor control. The system was comprised of a servo motor, servo lever arm, linkage with hinges on ends, and a lever arm on the landing gear.

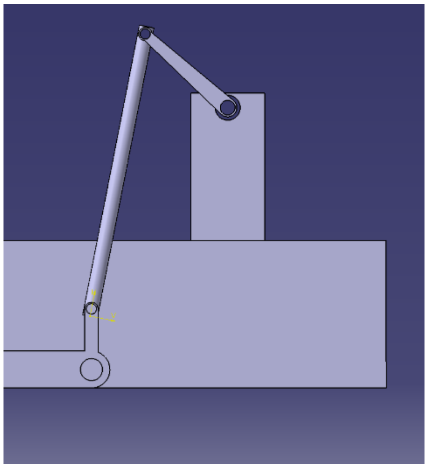
Image 1

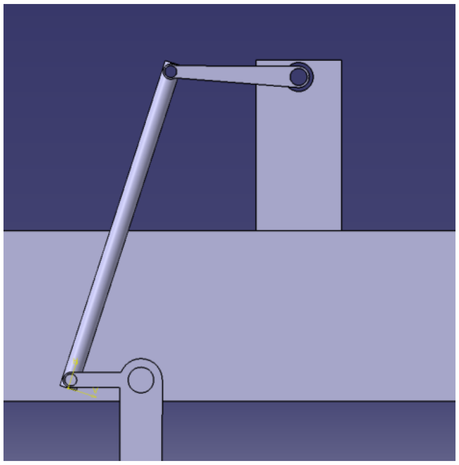
Image 2

Findings:

- Close to zero moment exerted by servo in retracted orientation (Image 1)
- Large moment exerted by servo in extended position (Image 2)
- Re-configuring components did not balance out end point moments

Kinematic Study 2:

Kinematic study 2 investigated the use of linear servo control. The system consisted of a linear servo and the rocker arm on the landing gear.

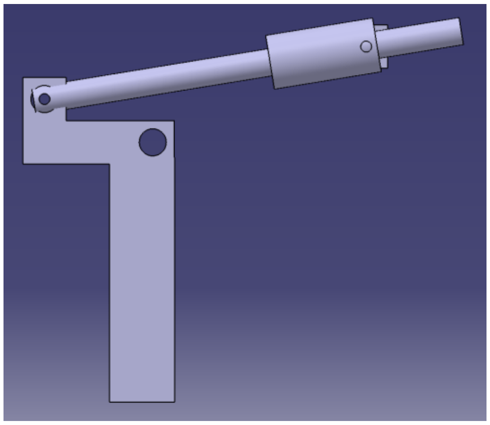
Image 3

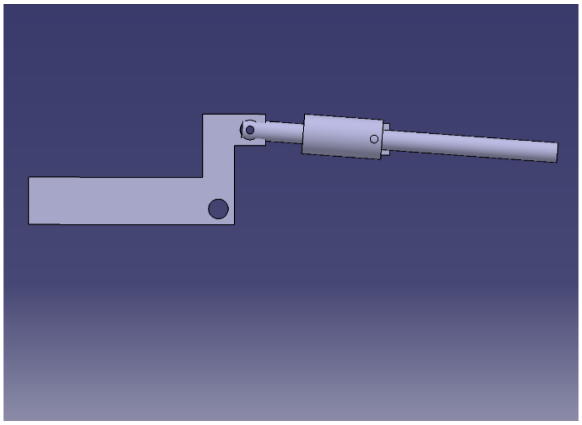
Image 4

Findings:

- Could maximize or minimize moments at either end
- Endpoint moments could be balanced
- Highly configurable for optimization

Kinematic Study Analysis

The results of the kinematic studies are analyzed and the decisions made are documented.

Kinematic Study 1

This study showed that using a rotary servo system is difficult to optimize. Based on the geometry of the system and spatial constraints of the drone, this system could not be reconfigured to optimize endpoint moments.

This system requires a servo motor with relatively large torque output adding design time, cost, power consumption, and possibly more weight. This design was discarded because the three criteria for a good mechanism were not met.

Kinematic Study 2

Kinematic study 2 proved this mechanism to be flexible in terms of design optimization. Varying the following values,

- Servo initial length
- Servo angle (relative to horizontal base plate of drone)
- Landing gear rocker arm angle (relative to vertical)
- Landing gear rocker arm length

allows the end point moments to be adjusted as needed with less geometrical restraint. The capability to optimize end point moments optimizes servo power requirements and cost. In addition, this design does not require a linkage rod, whereas the system from kinematic study 1 did. Finally, the design was found to fit efficiently into the casing of the drone, leaving good space for the controller and sensors. The three criteria for a good mechanism were met, and this design was selected for the drone.

Math Model Optimization

Because 4 values must be varied, MATLAB was used. A code was generated that ran iterations with a for loop. The servo motor initial length was found not to affect the results by a significant amount, so its value was guessed and defined. The length of the rocker arm was constrained spatially by the drone, and its value was chosen to be 3/8”. In addition, the landing gear is made of light plastic, and a large lever arm is not needed. It was intuitive what a good rocker arm angle would be to both maximize torque and prevent the components from colliding, so test values were not hard to guess. Finally, a range of values for the servo angle were input in a matrix.

The code is shown on the next page:

```
% Calculation Constraints
L=2;
theta1=[10:.07:43.236]; %Acutal Angle
RL=3/8;
theta2=30;
F=1;
sizee=size(theta1);

for ii=1:1:sizee(2)

 theta3(ii) = abs(180-90-theta2-theta1(ii));
 force(ii)=F*sind(theta3(ii));
 leverarm(ii) = RL;
 torque1(ii)=force(ii)*leverarm(ii);
 h1(ii)=RL*sind(90-theta2);
 h2(ii)=L*sind(theta1(ii));
 y(ii)=h1(ii)+h2(ii);
 x(ii)=L*cosd(theta1(ii))+RL*cosd(90-theta2);
 x1(ii)=RL*cosd(theta2);
 y1(ii)=RL*sind(theta2);
 x2(ii)=x(ii)+x1(ii);
 y2(ii)=y(ii)-y1(ii);
 Le(ii)=(x2(ii)^2+y2(ii)^2)^.5;
 theta4(ii)=atand(y2(ii)/x2(ii));
 torque2(ii)=F*sind(theta2+theta4(ii))*RL;
 stroke(ii)=Le(ii)-L;
end

subplot(2,2,1);
plot(theta1,torque1);
xlabel('Theta1 (deg)')
ylabel('Torque H.(in-lb)')
hold on
subplot(2,2,2);
plot(theta1,torque2);
xlabel('Theta1 (deg)')
ylabel('Torque V.(in-lb)')
hold on
subplot(2,2,3);
plot(theta1,stroke);
xlabel('Theta1 (deg)')
ylabel('Stroke (in)')
hold on
subplot(2,2,4);
plot(theta1,abs(torque1-torque2))
xlabel('Theta1 (deg)')
ylabel('Torqu H.-Torque V.(in-lb)')


%ideal_angle_index = find(abs(torque1-torque2)==min(abs(torque1-torque2)))
%Ideal_Angle = theta1(ideal_angle_index)
Stroke = min(stroke)
Torque_1 = min(torque1)
Torque_2 = max(torque2)
```

After adjusting the input values, it was clear that the following results are good optimized values:

- Servo initial length = 2”
- Servo angle = 40 deg
- Rocker arm angle = 30 deg
- Rocker arm length = 3/8”

The following plots were generated by the code and aided in the optimization process:

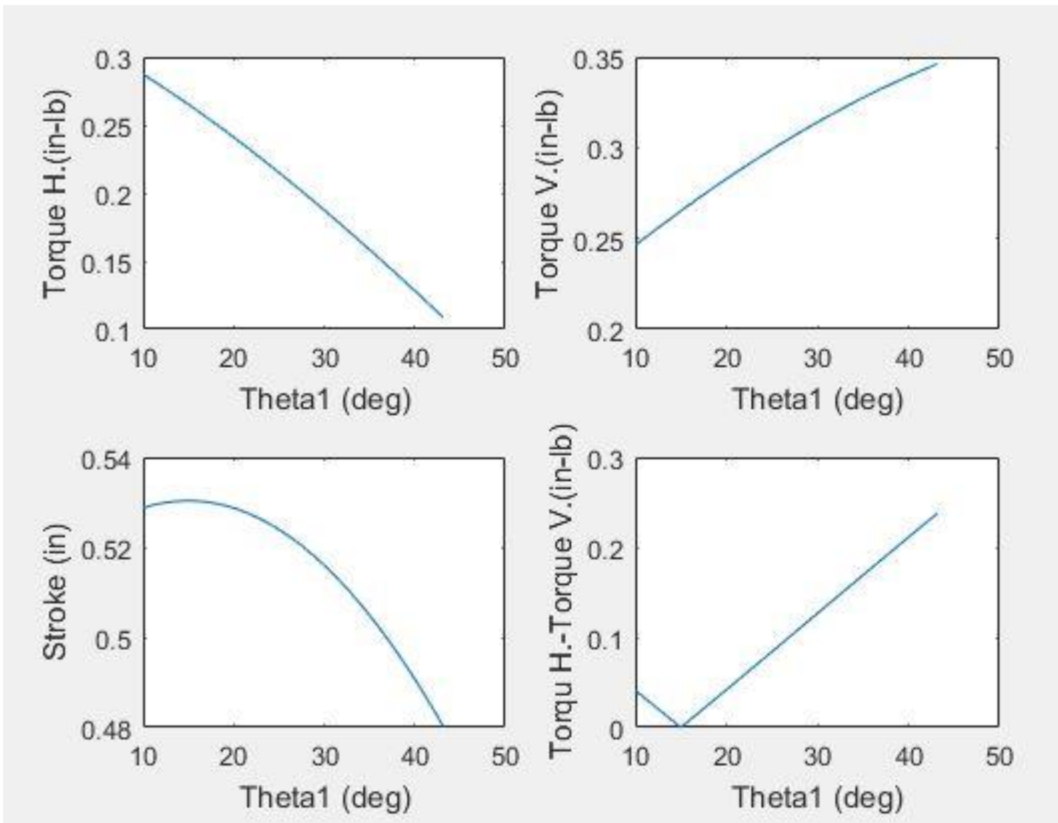

Image 5

The top two plots show that when the servo is orientated at 40 degrees, torque is minimized at the retracted position (horizontal) and maximized in the extended position (vertical). The lower left plot shows how stroke length varies with servo angle, and the lower right plot shows the difference of the endpoint moments.

Applying Math Model Results

Due to the spatial constraints within the drone, the two values characterizing the servo had to be altered as:

- Servo initial length = 1.084”
- Servo angle = 34.535 deg

The math model predicts the endpoint moments to be:

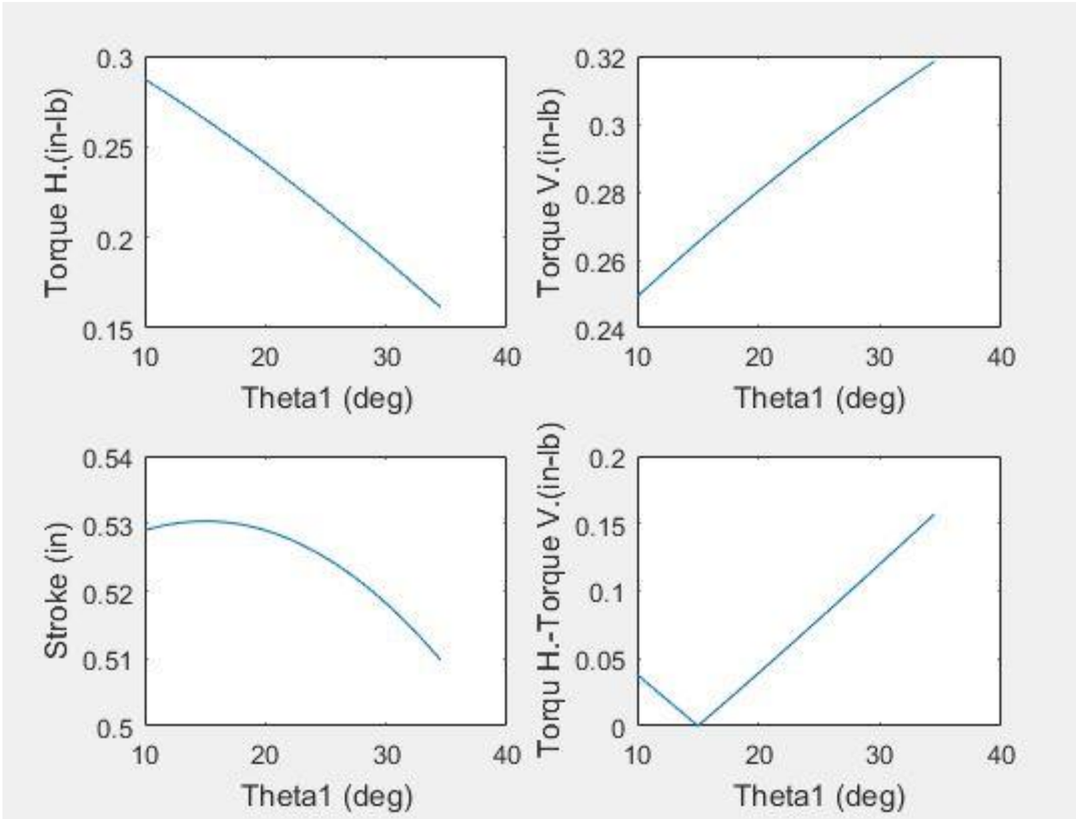

Image 6

Results Implemented in Design

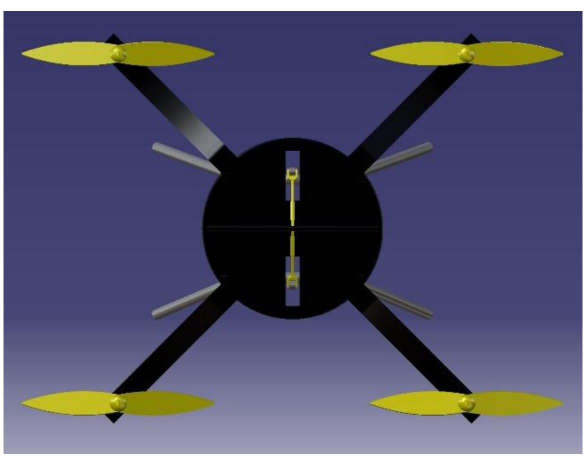

Image 7

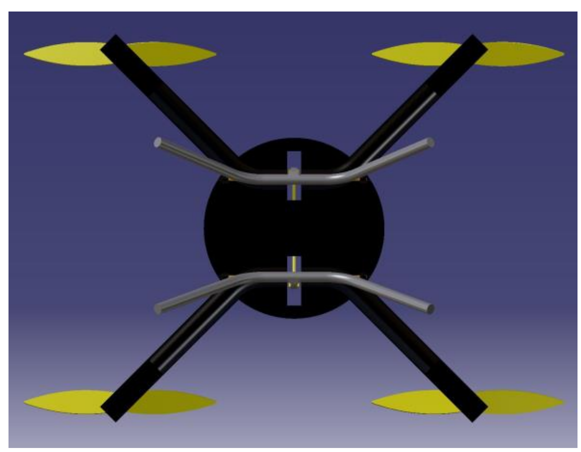

Image 8

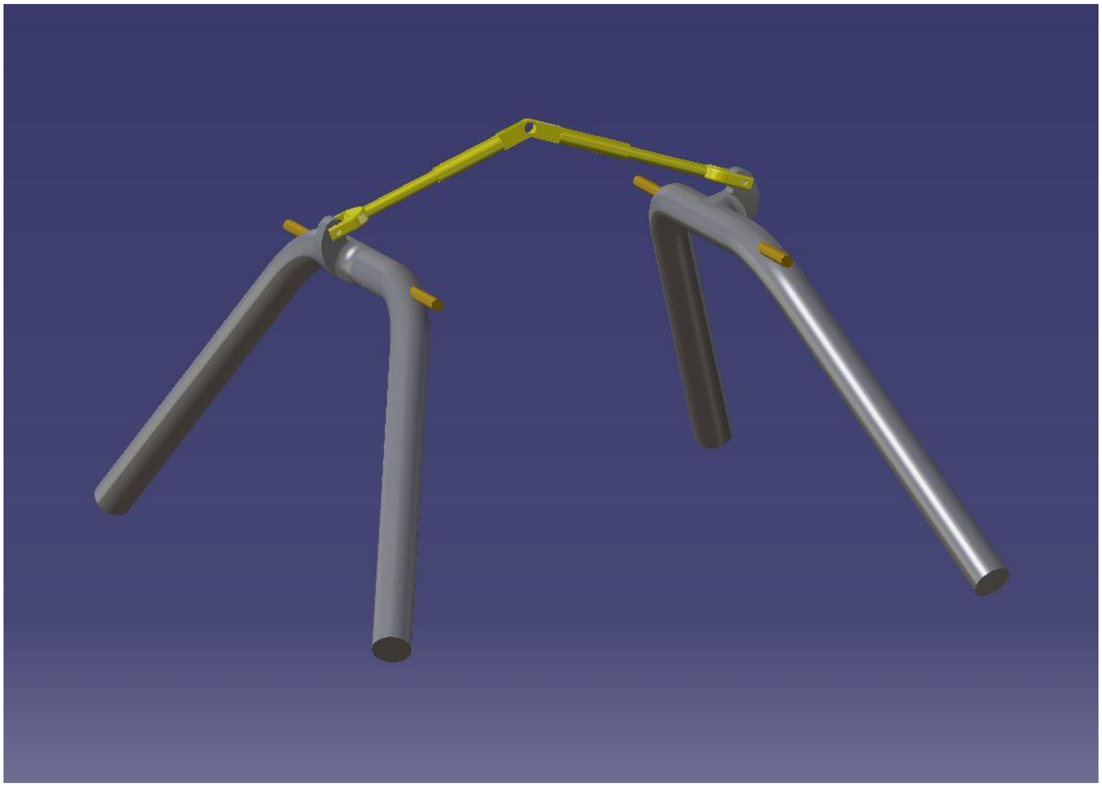

Image 9

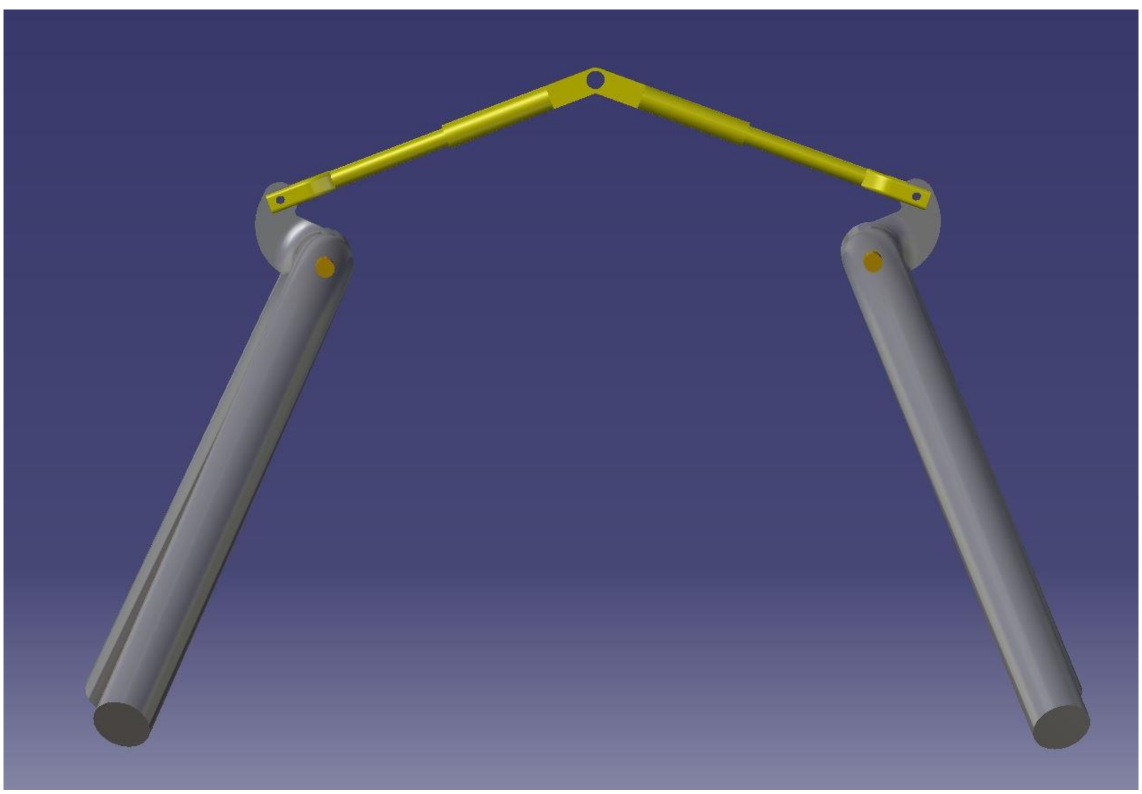

Image 10

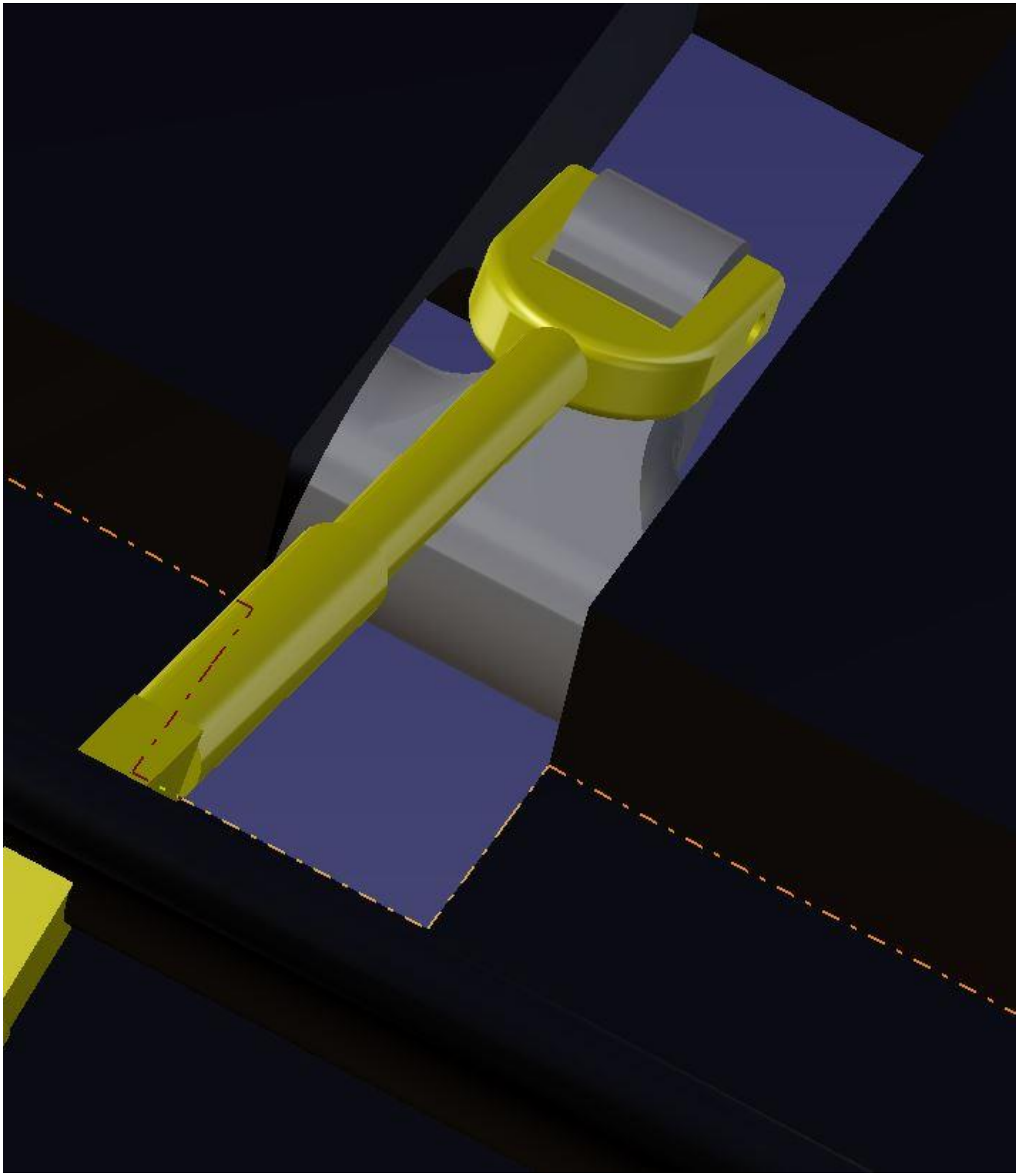

Image 11

Conclusion

The goal of this project was to begin the process of designing a quadcopter drone by designing folding in landing gear and specifying key dimensions. The math model did not take into account the spatial restrictions of the drone, but instead sought to aid in the optimization process by showing best case scenarios. The values had to be changed due to these restrictions and the results were reanalyzed with the math model. These values will be of use when selecting a servo.

Next steps for engineering the drone include:

- Purchase servos
- Design upper servo pin connection (discard straight shaft)
- Select motors
- Design motor mounts
- Add wire passages within drone arms
- Select propellers
- Program Arduino MEGA 2560 and integrate electronics
- 3D print parts and test
- Test and improve