Final Report

ROBOTICS - 41013

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1. Manipulate the World

1.1. Tool Offset

Using the information provided in Figure 1 we can use trigonometry, or knowledge of right-angled isosceles triangles, to deduce that the start of the blasting stream is 0.2m (200mm) away from the end-effector of the PUMA 560. The tool is also offset 45 degrees to ensure the z-axis is perpendicular to the ground (XY plane). This results in the following homogeneous transform:

```
tool_offset =

    0.7071         0   -0.7071         0
         0    1.0000         0         0
    0.7071         0    0.7071    0.2000
         0         0         0    1.0000
```

Figure 1: Tool offset transform

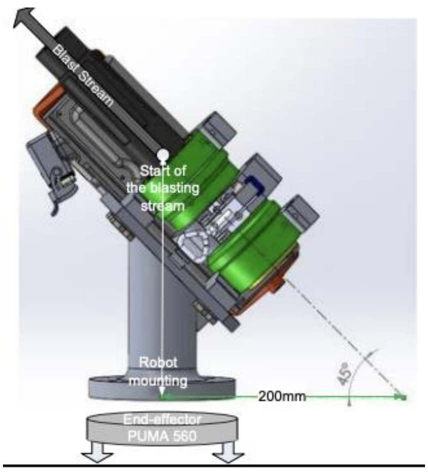


Figure 2: Blasting tool properties

1.2. Robot Base and Drum

The robot base has been placed at a position corresponding to my student number, 12621189. The drum has been carefully positioned on the floor, so it is reachable by the PUMA robot without reaching any singularities. Homogeneous transforms both these positions have been determined as well as the point between the drum and robot base.

```
% a) set base
robot_base_transform = transl([1.262, 1.189, 1]); % student number: 12621189

% b) drum transform
xoffset = 0.5;
yoffset = 1;
drum_transform = transl([xoffset, yoffset, 0]);

% c) calculate transform between base and drum
transform_between_base_and_drum = (robot_base_transform + drum_transform)/2;
```

Figure 3: Matlab code of homogeneous transforms

```
robot_base_transform =

    1.0000         0         0    1.2620
         0    1.0000         0    1.1890
         0         0    1.0000    1.0000
         0         0         0    1.0000


drum_transform =

    1.0000         0         0    0.5000
         0    1.0000         0    1.0000
         0         0    1.0000         0
         0         0         0    1.0000


transform_between_base_and_drum =

    1.0000         0         0    0.8810
         0    1.0000         0    1.0945
         0         0    1.0000    0.5000
         0         0         0    1.0000
```

Figure 4: Homogeneous transforms

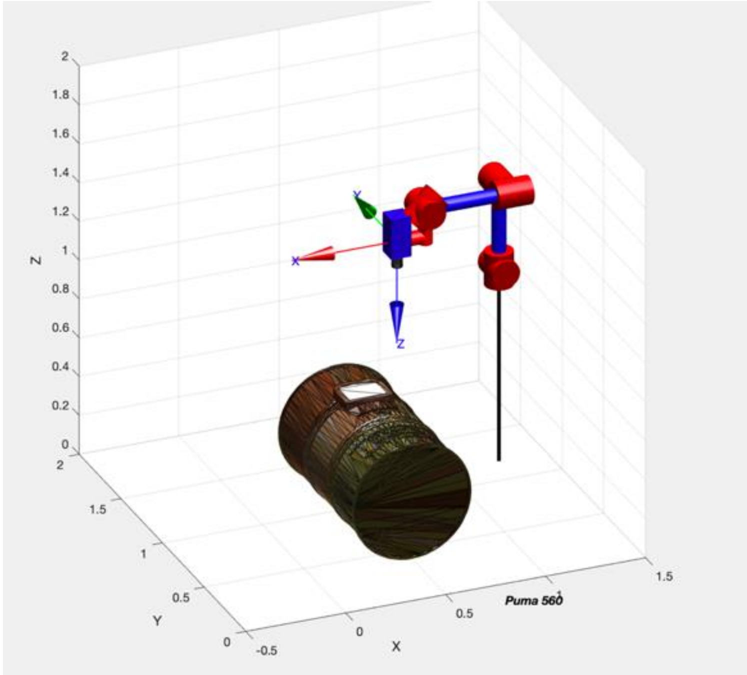
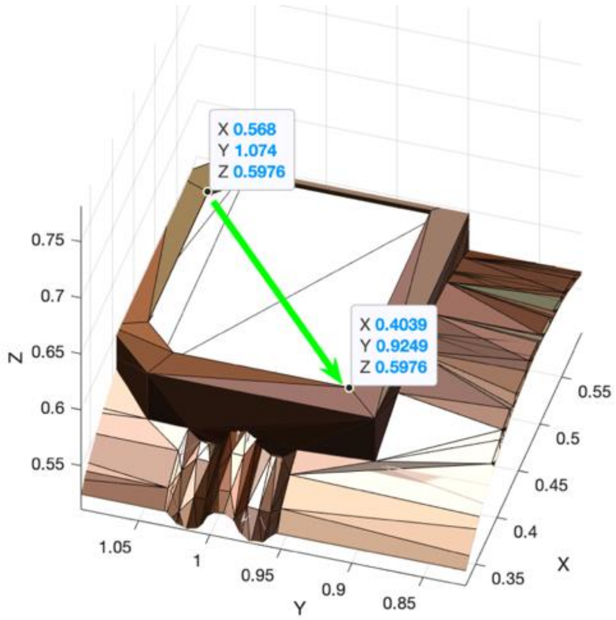


Figure 5: PUMA 560 and drum environment

1.3. Blast Path

Figure 6 displays the datatips of position 1 and position 2 as well as the direction of motion. The z values of both positions were increased by ~0.6m to raise the makeshift tool slightly above the plate.




```
pose_1 = [0.57 1.07 0.75];
pose_2 = [0.40 0.92 0.75];
```

Figure 6: Direction of motion from Position 1 to Position 2

```
tau_max = [97.6 186.4 89.4 24.2 20.1 21.3]';
qd_max = [8, 10, 10, 5, 5, 5]';
qdd_max = [10, 12, 12, 8, 8, 8]';
w = [0, 0, 209, 0, 0, 0]';

mass = 2.09;
grav = 9.81;
reaction = 209;
total_force = mass*grav - reaction;
total_mass = total_force/grav;
self.robot.payload(total_mass,[0;0;0]);

for i = 1:steps-1
    qdd(i,:) = (1/dt)^2 * (qMatrix(i+1,:) - qMatrix(i,:) - dt*qd(i,:));
    M = self.robot.inertia(qMatrix(i,:));
    C = self.robot.coriolis(qMatrix(i,:),qd(i,:));
    J = self.robot.jacob0(qMatrix(i,:));
    g = self.robot.gravload(qMatrix(i,:));
    tau(i,:) = (M*qdd(i,:)' + C*qd(i,:)' + g' + J'*w)' ;
```

Figure 7: Matlab code excerpt

1.4. Slow Blast Motion

The manipulator is translated from Position 1 to Position 2 while accounting for a payload (tool) of mass 2.09 kg and 209N reaction force. As seen earlier in Figure 5, the z-axis is perpendicular to the floor, hence the reaction for is travelling straight upwards. The trapezoidal velocity profile has been used to determine a joint matrix. Using a time of 0.75 seconds and delta time of 0.01, the manipulator travels slow and smooth enough to stay within the joint angles, velocity, acceleration, and torque limits as seen in Figure 8. Blue lines represent limits.

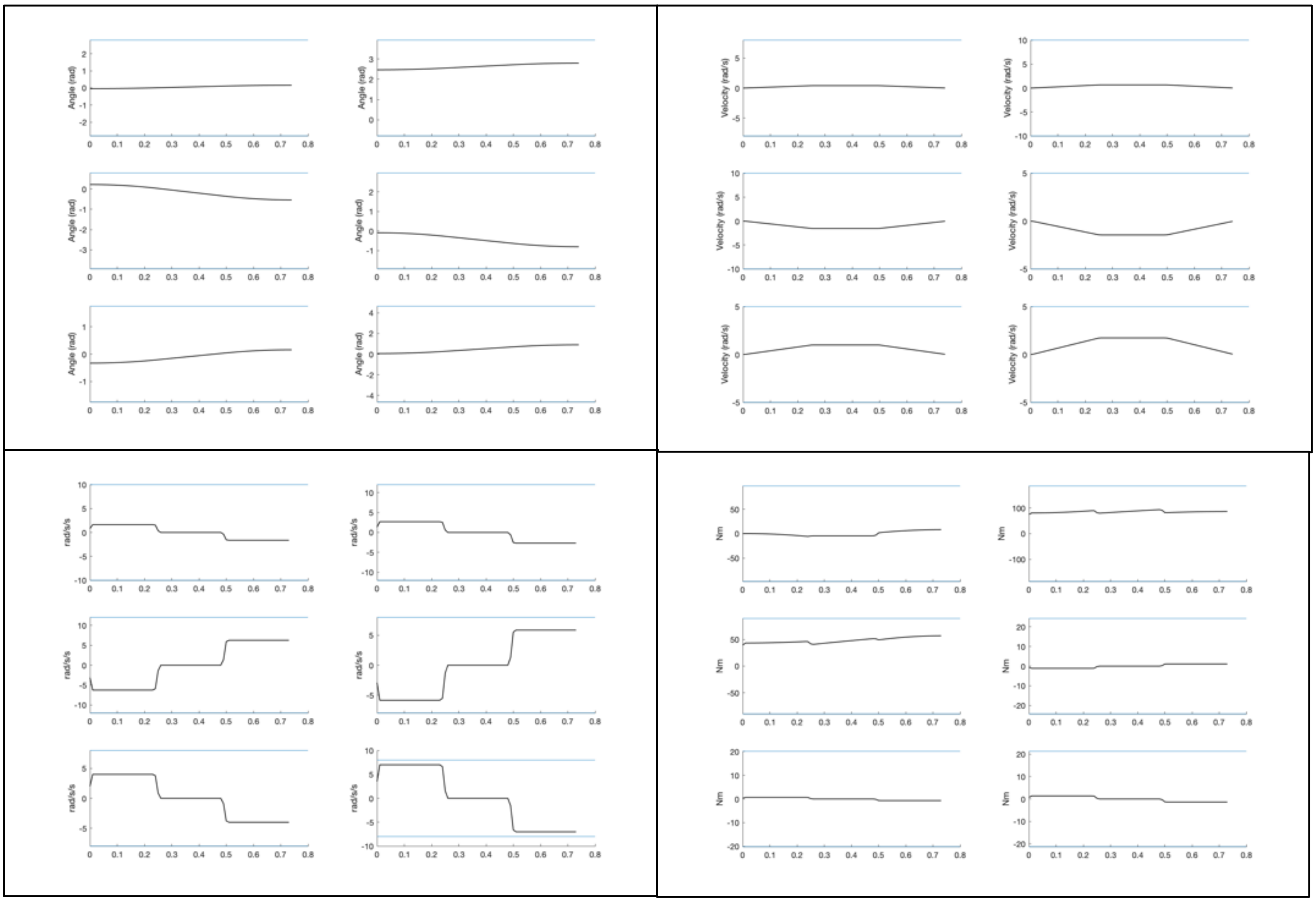


Figure 8: Slow Motion Limits; Angles (Top left), velocity (top right), acceleration (bottom left), torque (bottom right)

1.5. Overloaded Blast Motion

Using the same payload and delta time as previous, the time was adjusted to 0.68 seconds which managed to cause an acceleration overload in Joint 6. As can be seen in Figure 9, the first acceleration overload occurs from 0.02 seconds to approx. 0.21 seconds. The second overload occurs at approximately 0.47 seconds.

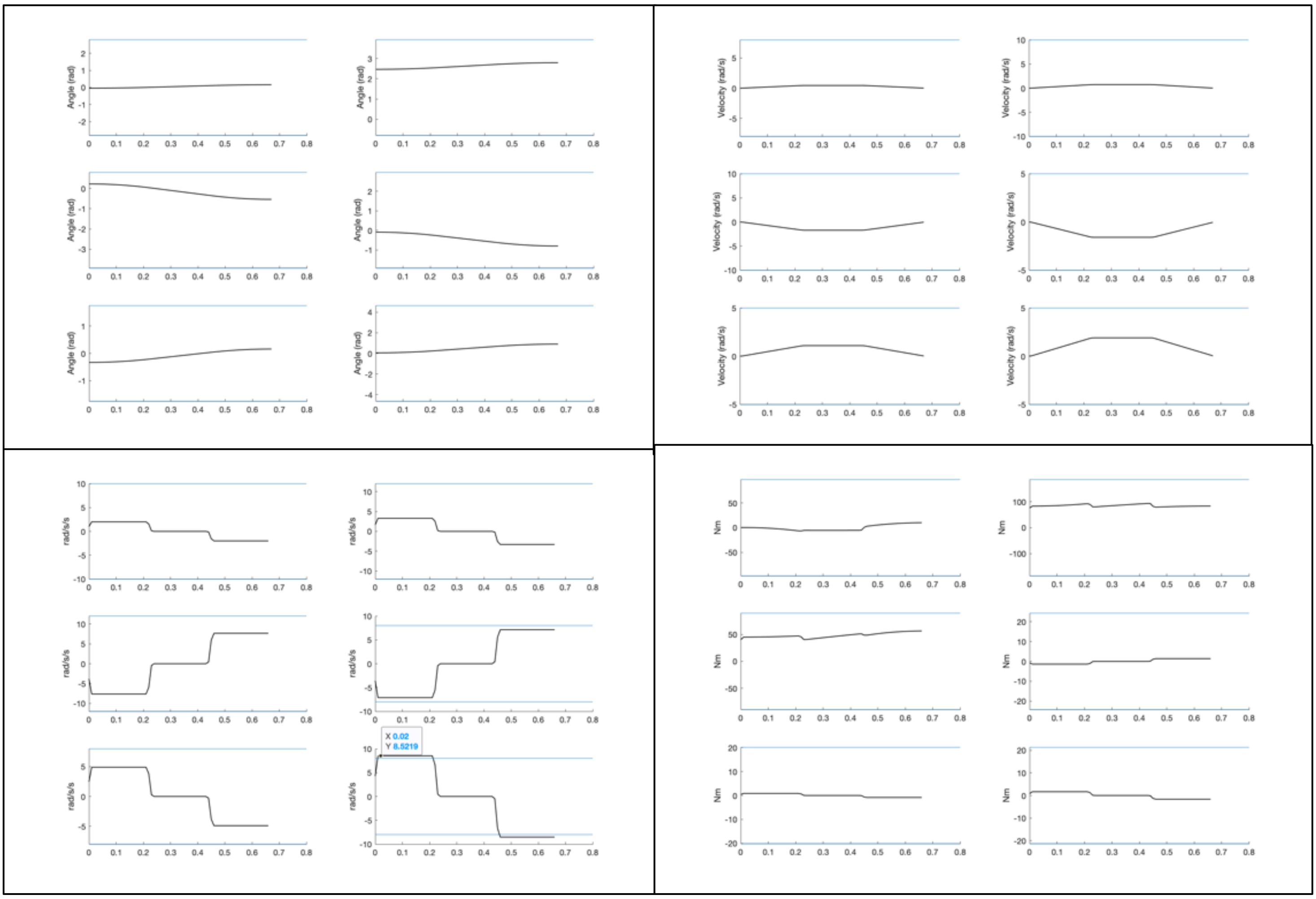


Figure 9: Overload Motion Limits; Angles (Top left), velocity (top right), acceleration (bottom left), torque (bottom right)

1.6. Code

Full code used is available at:

https://github.com/ajalsingh/robotics-uts/tree/master/Assignments/A4

2. Aquanaut – Underwater Robot Transformer

Videos:

https://www.youtube.com/watch?v=cdc5mQcJlqY

https://www.youtube.com/watch?v=4rJmF7xbQPI

Articles:

https://ieeexplore-ieee-org.ezproxy.lib.uts.edu.au/stamp/stamp.jsp?tp=&arnumber=8604508

https://spectrum.ieee.org/robotics/humanoids/meet-aquanaut-the-underwater-transformer

Aquanaut is an unmanned underwater robot developed by Houston Mechatronics Inc (HMI) that can transform itself from a long-distance deep-water submarine into a manipulator robot capable of completing complex underwater manipulation tasks. In submarine form, it can be used to travel to gas and/or oil rig equipment (or other sites) at speeds up to 13kph, reach depths unreachable by humans all while performing inspections and scans. It can then transform into humanoid form to expose its manipulators and perform maintenance.

Currently, deep-sea maintenance and inspection is performed using a remote operated underwater vehicle (ROV) which is tethered to a large support vessel and controlled by a crew. This is very expensive, and its operation is limited, therefore leading to the delay of crucial maintenance. The Aquanaut is intended to replace this outdated method while improving capability through the use of advanced sensors and AI and drastically reducing costs.

While it was developed primarily for oil and gas rig maintenance, I can see uses for the Aquanaut in marine research and hull inspection of large ships, both of which currently use ROVs. Although the robot's ability to 'transform' is a cool and exciting feature, I believe factors such as efficiency, usefulness and cost play a larger role in the success of robots.

3. Robots Affecting the World

3.1. Future Integration of Robotics

The Covid-19 pandemic has had a lasting effect on many industries throughout the world. The highest priority this year has been to maintain social distancing and hygiene practises to avoid further spreading the disease. The following article titled *'The rise of Covid Robots'* [1] displays images of robots developed and/or implemented as a result. We can see disinfectant and food handling/preparation robots being used for hygiene reasons, and robots for video calling and television broadcasting to encourage social distancing.

Prior to the pandemic, many believed that the use of robots and other highly precautionary measures were deemed useless or undesired as a disease in this scale was considered highly unlikely. I now believe some of these robots will be here to stay for good as nothing is impossible. Some workers may now be replaced by robots permanently [2]. This is especially true for higher risk jobs. I can see the wide scale introduction of regular deep cleaning robots into high congregation areas such as shopping centres, hospitals and workplaces as this would remove the risk of human cleaners becoming infected. These robots would also likely carry hand sanitizers for the general public to use.

Front line workers such as doctors and other medical professionals are almost always under direct threat of diseases. I believe we will start to see robots providing socially distanced consultations. One such robot is Tommy, who is able to measure "two crucial patient parameters; blood pressure and oxygen saturation" [3]. At some point in the greater future, if such a robot was mass produced and readily available for consumers to purchase as a home companion, I think it would be possible to get expert medical advice from anywhere in the world.

Factories and warehouses were already heading towards the Industrial Revolution 4.0. Workers were already being replaced by autonomous systems due to financial and efficiency reasons. While many other occupations were able to work from home during lockdown, factory workers were/are forced to risk their health to earn a living and continue to produce essential goods. Covid-19 has only sped up this industrial revolution as a result of social distancing practices [4][5]. As more and more companies learn the advantages of robots, I expect to see factories that are mostly or even fully automated in the near future. This realisation could also bleed out into other industries who may choose to replace humans with robots.

Theoretically, it is easy to predict future adaption of robots based on factors such as cost, efficiency, safety, etc. However, customer service is also a factor that should be considered and can prevent the wide-scale adaption of robots. Unlike you and I, there are many people in the world who do not like the introduction robotics and AI and prefer human interaction [6]. Humans are better able to understand and empathize than robots can. In situations such as restaurants where food ordered is not to standard, a waiter can empathize and offer a replacement or discount of some sort to maintain satisfaction. What would a robot do in this situation? What if the robot cannot identify the hair (or something else) in the food and hence upsets the customer?

On another note, while playing a recently released game, 'Watch Dogs: Legion', set in the near future (yeah, I know I should be studying), I couldn't help but notice all the different types of drones constantly flying above the city streets. Two drones that stand out are the parcel delivery drones and surveillance drones. Although I don't see this happening within the next five years, drones for package delivery is a great way to not only avoid traffic and possibly deliver goods faster (ignoring weather conditions and payload capabilities) I think it's a great way to maintain social distancing. The surveillance drones could also be used to perform temperature checks and identify people who show signs of illness (coughing, sneezing, etc). Mobile robots could also be used to achieve this on the ground.

3.2. Robot and Frank

In the film Robot and Frank, we see a socially assistive robot introduced to an elderly patient (Frank) with mental disorientation. The robot's sole purpose is to aid him in his day-to-day activities. A study into socially assistive robots for the elderly identifies multiple User Needs that a robot should/must be able to accomplish [7]. Such needs are providing timely reminders for medication, provide motivation for exercise and raise an alarm during emergencies or wrongdoings. I believe the robot in this film is capable of doing such tasks as we see Frank taking a hike in the trailer, however, I have noticed some aspects that are not quite true to reality at this point in time.

One major technical aspect which is completely ignored in this movie is battery management and recharging. While viewing the trailer and various clips available on YouTube, I noticed the robot would be in operation before Frank is awake and late into the night. As with any electronic device, the more you use it the greater the battery consumption. This means the robot should discharge more if was on a hike with all four manipulators moving (legs included) than if it were standing around all day. The robot is also able to dynamically adapt to its environment, all while learning new things (lock picking) and maintaining somewhat smooth manipulator movements [8] (also avoiding singularities and collisions). With all this in mind, current robots such as Honda's Asimo can only last for one hour on a single battery charge and takes a further three hours to fully charge [9].

In the trailer, we hear frank say, *"I would rather die eating cheeseburgers than live off steamed cauliflower."* Most humans in this day and age would understand the sarcasm and the meaning behind such a statement. But how would a robot be able to detect not only this sarcasm but also the tone and emotion of their human companion? This notion of Humanoid service robots as a daily companion is further discussed in an article based on effective service humanoids [10].

This article also introduces the idea of distributed collaboration and continuous learning where data is shared between multiple robots. As with any Big Data and Artificial Intelligence application, data security and privacy for individuals and households is a big discussion topic. In this film, the robot reminds Frank that its memory can be used against him. We are yet to become unanimous on a method of data handling and protection. There is an argument for increased surveillance and protection by allowing authorities to freely access this data, but there is also the 'Big Brother' issue where the world will become over-policed and hence depriving individuals of their freedom.

Throughout the past semester, I have been studying the reliability of artificial intelligence as my capstone project. Hence, I know that AI has its limitations, in particular in training and operational/deployment environments. This is evident when we see Frank teaching the robot how to pick a lock. While it may be accurate, efficient and quick at his home (training environment), there is a fair chance the robot will fail in the real situation due to many different variables such as time of day and amount of light visible. In reality, such failures could have unfortunate consequences [11][12].

Finally, it appears the robot in this film is completely autonomous, meaning that is unmanned and unsupervised. Based on work completed on FetchRecycle project for assignment 2, we often had to take avoiding action in certain situations. There were times were AR markers were not visible or read correctly and there were also times where out position estimation wasn’t as accurate as desired. While there are very reputable companies who have accomplished great things in robotics, I find it hard to believe that companion humanoids are currently capable of operating unsupervised.

4. References

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[2] Thomas, Z. (2020). Will Covid-19 accelerate the use of robots at work? *BBC News*. [online] 19 Apr. Available at: https://www.bbc.com/news/technology-52340651.

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[12] Saria, S., & Subbaswamy, A. (2019). Tutorial: Safe and Reliable Machine Learning. In ACM Conference on Fairness, Accountability, and Transparency (FAT* 2019). [Accessed 14 August 2020].

5. Self-Assessment

Section	Task	Task Mark	Self-Assessment	Notes
Manipulate the world	Show calculations	4	**4**	Calculations & explanation provided
	Base & Drum transforms	4	**4**	Base location according to student number, all transforms provided
	Starting pose	2	**2**	Used data tips to find poses
	Slow motion	10	**8**	Performs successful blast, payload accounted for, I think reaction force accounted for as well
	Overloaded motion	15	**13**	Performs successful blast, payload accounted for, I think reaction force accounted for as well. Failure identified
Robots Affecting the World	Week 11 preso	8	**6**	I did ok, could've done better
	Teams post	8	**7**	Article and video provided, presented my findings
	Teams comment	4	**3**	Commented under Linh Tran's post about Intel OpenBot
	Robots in the next 5 years	20	**16**	Provided 5 required sources, met min word count, discussed multiple ideas and opinions. Went for quantity over in-depth discussion on 1 topic
	Robot & Frank	20	**16**	Provided 5 required sources, met min word count, discussed multiple ideas and opinions. Went for quantity over in-depth discussion on 1 topic
Self-Assessment		1	**1**	done