

Robotic Flight Simulator



Presented By: Austin Kucinski, Heath Palmer, & Nathan Huber

Team Members

- **Austin Kucinski (EET)**
 - 3 Semesters at Cincinnati Test Systems as Controls Engineer Co-Op
 - 2 Semesters at Automation Plus as Control Systems Co-Op
- **Heath Palmer (EET)**
 - 2 Semesters at KLH Engineering as Electrical Engineer Co-Op
 - 3 Semesters at Intelligrated as EE Project Management Co-Op
- **Nathan Huber (EET)**
 - 8 Semesters at Coldwater Machine as Controls & Robotics Engineer Co-Op
- Advisor: Professor Rabiee & Dr. Ma

Overview

Using vision tracking and a robotic arm, a user will be able to interact with a small standardized aircraft control panel without the need of a full-production control panel.

Problem

Flight simulators are costly to build and are not interchangeable between different flight models.



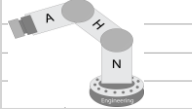
Figure 1: Boeing 737 Flight Simulator [1]

Solution

Develop an autonomous robotic system that will manipulate a standardized flight control panel around the user using a camera to determine the user's head angle.

Gantt Chart

Robotic Flight Simulator



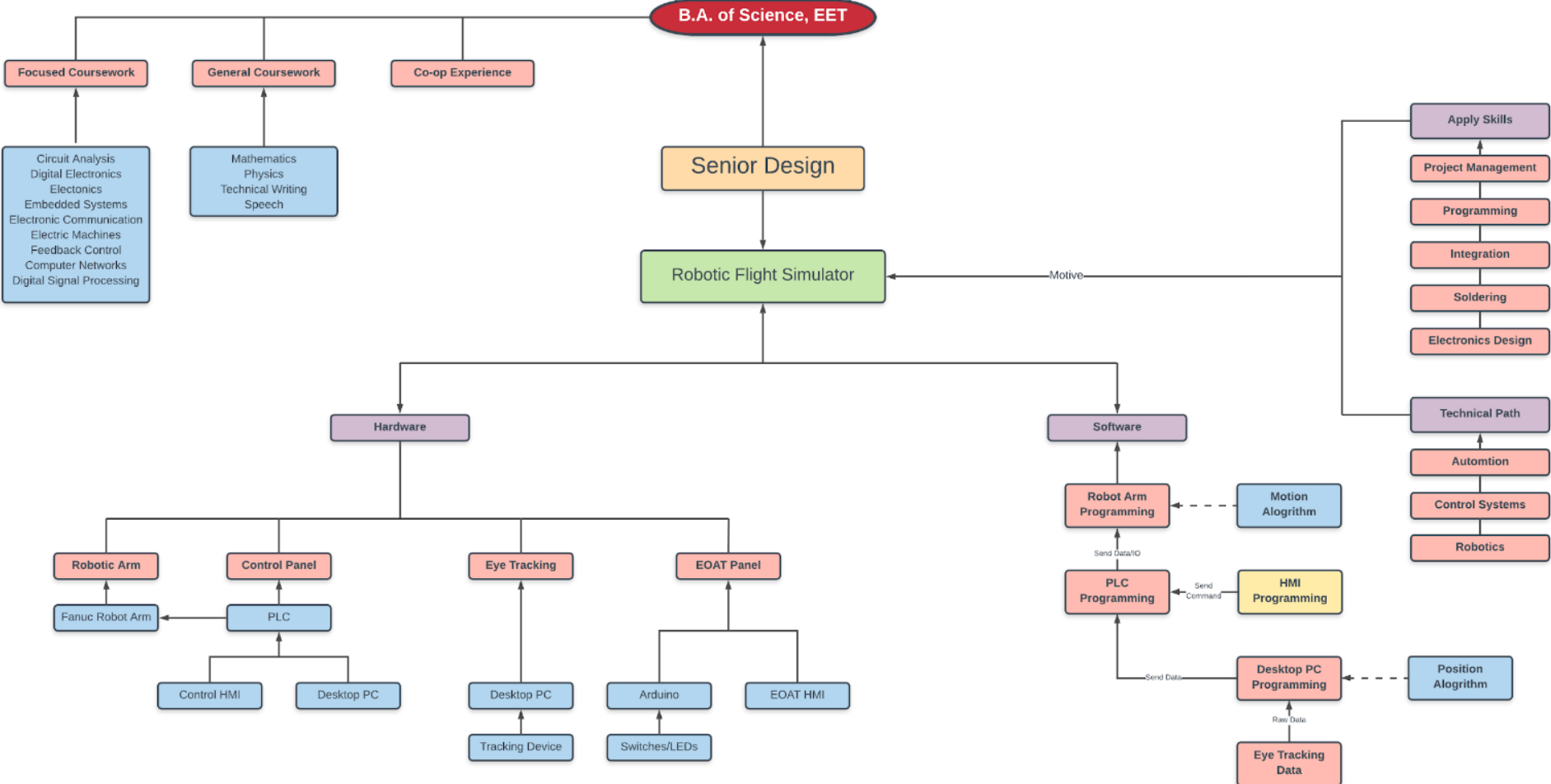
Project Lead: Austin, Heath, Nathan
 Start Date: 10/1/2018 Monday

Today's Date: 4/1/2019 Monday

First Day of Week (Mon=2): 2

WBS	Tasks	Task Lead	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining																			
										01 - Oct - 18	08 - Oct - 18	15 - Oct - 18	22 - Oct - 18	29 - Oct - 18	05 - Nov - 18	12 - Nov - 18	19 - Nov - 18	26 - Nov - 18	03 - Dec - 18	10 - Dec - 18	17 - Dec - 18	24 - Dec - 18	31 - Dec - 18	07 - Jan - 19	14 - Jan - 19	21 - Jan - 19	28 - Jan - 19	04 - Feb - 19
1	Control Panel (185 Hours)	Austin	10/1/18	2/28/19	151	55%	109	83	68																			
1.1	Control Panel Hardware Design (20 Hours)	Austin	10/1/18	11/16/18	47	100%	35	47	0																			
1.2	EOAT Panel Hardware Design (20 Hours)	Austin	10/1/18	11/16/18	47	100%	35	47	0																			
1.3	Control Panel Assembly (40 Hours)	Austin	2/1/19	2/15/19	15	0%	11	0	15																			
1.4	EOAT Panel Assembly (40 Hours)	Austin	12/30/18	2/22/19	55	80%	40	44	11																			
1.5	PCB Manufacturing (EOAT & Control) (15 Hours)	AK & NH	12/30/18	2/8/19	41	80%	30	32	9																			
1.6	Arduino Programming (20 Hours)	Austin	2/1/19	2/20/19	20	28%	14	5	15																			
1.7	Debug (30 Hours)	Austin	2/20/19	3/11/19	20	0%	14	0	20																			
2	Camera Integration (114 Hours)	Heath	10/1/18	2/28/19	151	119%	109	180	-29																			
2.1	Market Research (10 Hours)	Heath	10/1/18	11/3/18	34	100%	25	34	0																			
2.2	Literature Review (10 Hours)	Heath	10/1/18	11/3/18	34	80%	25	27	7																			
2.3	Integration Research (10 Hours)	Heath	11/4/18	11/9/18	6	100%	5	6	0																			
2.4	Hardware Setup (25 Hours)	Heath	11/15/18	12/14/18	30	100%	22	30	0																			
2.5	Software Setup (25 Hours)	Heath	12/14/18	1/12/19	30	90%	21	27	3																			
2.6	Troubleshooting (16 Hours)	Heath	1/13/19	2/28/19	47	100%	34	47	0																			
2.7	System Integration (16 Hours)	Heath	2/20/19	2/28/19	9	100%	7	9	0																			
3	Robotic Programming (122 Hours)	Nathan	10/1/18	2/28/19	151	121%	109	182	-31																			
3.1	Purchasing (15 Hours)	Nathan	10/1/18	10/22/18	22	100%	16	22	0																			
3.2	Shipping (10 Hours)	Nathan	10/23/18	12/7/18	46	80%	36	36	10																			
3.3	Software Programming (50 Hours)	Nathan	11/15/18	12/28/18	44	100%	32	44	0																			
3.4	Wire Assembly (10 Hours)	Nathan	12/14/18	1/12/19	30	100%	21	30	0																			
3.5	Communication & IO (2 Hours)	Nathan	1/12/19	1/14/19	3	100%	1	3	0																			
3.6	Initial Startup (10 Hours)	Nathan	1/14/19	1/17/19	4	100%	4	4	0																			
3.7	Debug (25 Hours)	Nathan	1/17/19	2/28/19	43	100%	31	43	0																			
4	PLC (42 Hours)	Nathan	11/1/18	2/28/19	120	89%	86	107	13																			
4.1	Software Programming (30 Hours)	Nathan	11/1/18	12/31/18	61	100%	43	61	0																			
4.2	Communication (2 Hours)	Nathan	1/12/19	1/14/19	3	100%	1	3	0																			
4.3	Debug (10 Hours)	Nathan	1/17/19	2/28/19	43	100%	31	43	0																			
5	HMI (37 Hours)	Nathan	11/1/18	2/28/19	120	89%	86	107	13																			
5.1	Software Programming (25 Hours)	Nathan	11/1/18	12/31/18	61	100%	43	61	0																			
5.2	Communication (2 Hours)	Nathan	1/12/19	1/14/19	3	100%	1	3	0																			
5.3	Debug (10 Hours)	Nathan	1/17/19	2/28/19	43	100%	31	43	0																			
6	Presenting (80 Hours)	Team	10/1/18	4/16/19	198	0%	142	0	198																			
6.1	Technical Design Reviews (Oral) (20 Hours)	Team	10/1/18	11/16/18	47	0%	35	0	47																			
6.2	Construct Poster (40 Hours)	Team	3/1/19	3/31/19	31	0%	21	0	31																			
6.3	Tech Expo (20 Hours)	Team	4/1/19	4/16/19	16	0%	12	0	16																			

Concept Map



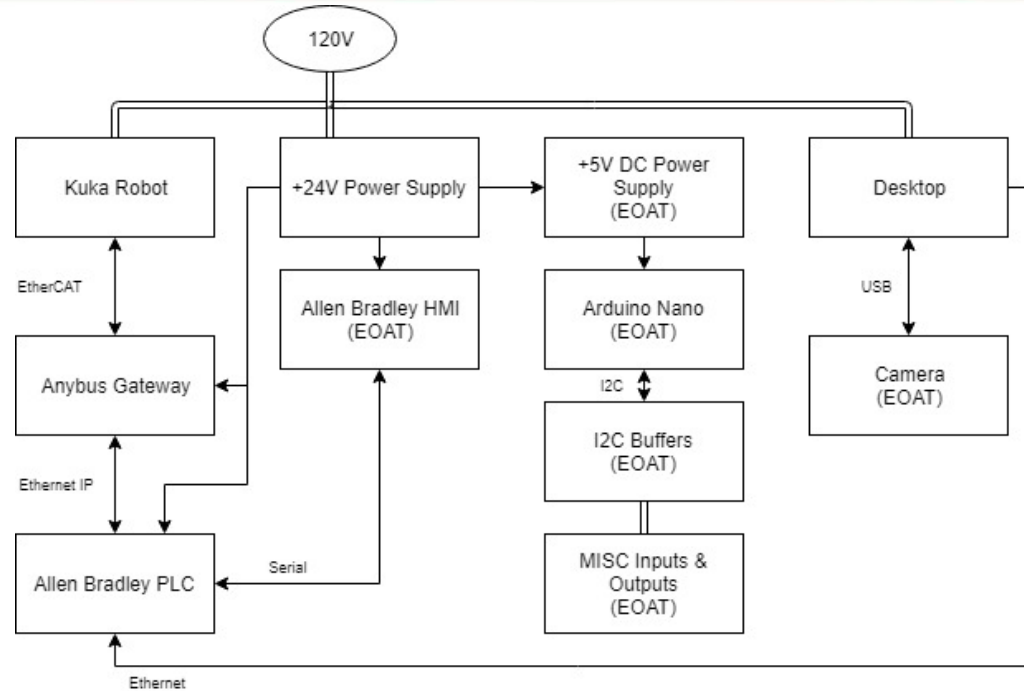


Figure 2: System Overview

Senior Design: Robotic Flight Simulator (1/3)								
Bill of Material								
Members: Nathan H, Austin K, & Heath P							University Funded	
							Personally Funded	
Line Item:	Qty:	Catalog Number:	Description:	Manufacturer:	Vendor:	Supplier:	Unit Cost:	Total Cost:
1000	1	CR35-1A	Fanuc Robot	Fanuc	Fanuc America	University of Cincinnati	\$45,710.00	\$45,710.00
1001	1	Software Options	Robot Software Additions	Fanuc	Fanuc America	University of Cincinnati	\$9,828.90	\$9,828.90
1002	1	R820-14	Kuka iiva	Kuka	Kuka	University of Cincinnati	\$50,000.00	\$50,000.00
1003	1	C600	AB HMI 6"	AllenBradely	Rockwell	University of Cincinnati	\$500.00	\$500.00
1004	1	1769-L23E-QB1B	CompactLogix PLC	AllenBradely	Rockwell	University of Cincinnati	\$1,200.00	\$1,200.00
1005							\$0.00	\$0.00
1006	1	Loctech - C920 Web Cam	C920 Web Cam	Loctech	Loctech	Heath Palmer	\$50.00	\$50.00
1007							\$0.00	\$0.00
1008	2	A-1640	Rotary Switch 4 Pole 3 Position	Tayda Electronics	Tayda	Austin Kucinski	\$0.89	\$1.78
1009	3	A-5098	Black Plastic Knob with Green Pointer	Tayda Electronics	Tayda	Austin Kucinski	\$0.22	\$0.66
1010	5	A-322	Black Plastic Knob with White Pointer	Tayda Electronics	Tayda	Austin Kucinski	\$0.22	\$1.10
1011	3	A-1962	1K OHM Linear Taper Potentiometer	Tayda Electronics	Tayda	Austin Kucinski	\$0.50	\$1.50
1012	5	A-706	LED 5mm Red	Tayda Electronics	Tayda	Austin Kucinski	\$0.02	\$0.10
1013	5	A-057	LED 5mm Green	Tayda Electronics	Tayda	Austin Kucinski	\$0.03	\$0.15
1014	5	A-407	LED 5mm Blue	Tayda Electronics	Tayda	Austin Kucinski	\$0.05	\$0.25
1015	5	A-1583	LED 5mm Yellow	Tayda Electronics	Tayda	Austin Kucinski	\$0.03	\$0.15
1016	5	A-4567	Mini Toggle Switch SPDT On-On	Tayda Electronics	Tayda	Austin Kucinski	\$0.47	\$2.35
1017	3	A-179	LM7805 Voltage Regulator	Tayda Electronics	Tayda	Austin Kucinski	\$0.23	\$0.69
1018	50	A-2115	10K OHM 1/4W 5% Resistor	Tayda Electronics	Tayda	Austin Kucinski	\$0.01	\$0.50
1019	5	A-001	8 pin DIP IC Socket Adaptor	Tayda Electronics	Tayda	Austin Kucinski	\$0.03	\$0.15
1020	5	A-1601	28 pin DIP IC Socket Adaptor	Tayda Electronics	Tayda	Austin Kucinski	\$0.11	\$0.55
1021	1	A-5162	Copper Chd Board PCB	Tayda Electronics	Tayda	Austin Kucinski	\$1.89	\$1.89
1022	20	A-2119	220 OHM 1/4W 5% Resistor	Tayda Electronics	Tayda	Austin Kucinski	\$0.01	\$0.20
1023	10	A-2067	330 OHM 1/4W 5% Resistor	Tayda Electronics	Tayda	Austin Kucinski	\$0.01	\$0.10
1024	16	A-2940	PCB support with Adhesive Back	Tayda Electronics	Tayda	Austin Kucinski	\$0.10	\$1.60
1025	1	A-2849	Knurled Aluminum Black Knob	Tayda Electronics	Tayda	Austin Kucinski	\$1.29	\$1.29
						University Funded:	\$107,288.90	\$107,288.90
						Personally Funded:	\$288.87	\$382.80
						Group:	\$288.87	\$382.80
						Total Cost:	\$107,577.77	\$107,671.70

Senior Design: Robotic Flight Simulator (2/3)								
Bill of Material								
Members: Nathan H, Austin K, & Heath P							University Funded	
							Personally Funded	
Line Item:	Qty:	Catalog Number:	Description:	Manufacturer:	Vendor:	Supplier:	Unit Cost:	Total Cost:
1026	1	A-4557	Knob DAVIES 1900H CLONE Red	Tayda Electronics	Tayda	Austin Kucinski	\$0.42	\$0.42
1027	1	A-389	Davies 1510 Clone Red Knob	Tayda Electronics	Tayda	Austin Kucinski	\$0.42	\$0.42
1028	1	-	0.56" 4-Digit 7-Segment Display Bezel	Tindie	Tindie	Austin Kucinski	\$4.99	\$4.99
1029	6	-	16mm push button LED square blue	BENKPAK	AliExpress	Austin Kucinski	\$1.10	\$6.60
1030	1	1442	16mm LED push button red latching	Adafruit	Adafruit	Austin Kucinski	\$1.50	\$1.50
1031	1	559	Metal pushbutton Red LED Ring	Adafruit	Adafruit	Austin Kucinski	\$4.95	\$4.95
1032	1	a17031000ux0114	Emergency Stop Push Button	Uxcell	Amazon	Austin Kucinski	\$9.99	\$9.99
1033	1	CXCP212C	Red Cover Rocker Toggle Switch 5	ESUPPORT	Amazon	Austin Kucinski	\$10.19	\$10.19
1034	1	B016RG90GQ	7-segment Display W/2c Backpack	Adafruit	Amazon	Austin Kucinski	\$12.12	\$12.12
1035	1	-	I2C Bus Extender/Buffer pack of 5	FXI Electronics	AliExpress	Austin Kucinski	\$3.67	\$3.67
1036	10	593-3210C	VCC Clear Fresnel 5mm / LED Lenses	VCC	Mouser	Austin Kucinski	\$0.46	\$4.56
1037	10	593-RNG268	VCC RETAINING RING	VCC	Mouser	Austin Kucinski	\$0.24	\$2.37
1038							\$0.00	\$0.00
1039							\$0.00	\$0.00
1040	2	PCB	Circuit Board	Tayda Electronics	Tayda	Nathan Huber	\$2.99	\$5.98
1041	1	-	Main Electrical Control Panel	-	-	Nathan Huber	\$25.00	\$25.00
1042	1	-	Hardware (Bolts, Screws, Wire Ties)	-	-	Austin & Nathan	\$25.00	\$25.00
1043	1	-	Steel (BO AT Panel Mount)	-	-	Nathan Huber	\$50.00	\$50.00
1044	1	-	DIN Rail pack of 5	AliExpress	AliExpress	Austin Kucinski	\$6.64	\$6.64
1045	3	RT18-32X	10x38mm DIN Rail Mount Fuse Holder	May's	AliExpress	Austin Kucinski	\$1.52	\$4.56
1046	5	C10G2	Fuse, 2A, 10X39mm	Bussman/Eaton	Newark	Austin Kucinski	\$0.98	\$4.90
1047	2	C10G4	Fuse, 4A, 10X39mm	Bussman/Eaton	Newark	Austin Kucinski	\$1.72	\$3.44
1048	1	-	Wire tube	-	Home Depot	Austin Kucinski	\$2.00	\$2.00
1049	2	-	Charcoal Spray paint	Rustoleum	Home Depot	Austin Kucinski	\$4.00	\$8.00
1050							\$0.00	\$0.00
						University Funded:	\$107,288.90	\$107,288.90
						Personally Funded:	\$288.87	\$382.80
						Group:	\$288.87	\$382.80
						Total Cost:	\$107,577.77	\$107,671.70

Senior Design: Robotic Flight Simulator (3.3)								
Bill of Material								
Members: Nathan H, Austin K, & Heath P							University Funded	
							Personality Funded	
Line Item:	Qty:	Catalog Number:	Description:	Manufacturer:	Vendor:	Supplier:	Unit Cost:	Total Cost:
1051							\$0.00	\$0.00
1052	1	1	Null Modem Cable 10ft	Generic	Amazon	Nathan Huber	\$7.39	\$7.39
1053	7	Generic	Ethernet Cables	Generic	Amazon	Nathan Huber	\$7.00	\$49.00
1054	1	Generic	16 Awg Wiring	Generic	Amazon	Nathan Huber	\$20.00	\$20.00
1055	1	Generic	16 Awg Wiring - 4 Cond	Generic	Amazon	Nathan Huber	\$20.00	\$20.00
1056	70	A-4995	AWG 22 White Wire 1FT (30cm) Solid	Tayda Electronics	Tayda	Austin Kucinski	\$0.09	\$6.30
1057	70	A-4999	AWG 22 Blue Wire 1FT (30cm) Solid	Tayda Electronics	Tayda	Austin Kucinski	\$0.09	\$6.30
1058	5	A-4902	20cm Blue Heat Shrink Tubing 1.5mm	Tayda Electronics	Tayda	Austin Kucinski	\$0.10	\$0.50
1059	5	A-4905	20cm White Heat Shrink Tubing 1.5mm	Tayda Electronics	Tayda	Austin Kucinski	\$0.10	\$0.50
1060	5	A-4909	20cm Blue Heat Shrink Tubing 3.5mm	Tayda Electronics	Tayda	Austin Kucinski	\$0.10	\$0.50
1061	5	A-4912	20cm White Heat Shrink Tubing 3.5mm	Tayda Electronics	Tayda	Austin Kucinski	\$0.10	\$0.50
1062	5	A-4918	20cm Black Heat Shrink Tubing 6mm	Tayda Electronics	Tayda	Austin Kucinski	\$0.14	\$0.70
1063	5	A-4931	20cm Green Heat Shrink Tubing 10mm	Tayda Electronics	Tayda	Austin Kucinski	\$0.16	\$0.80
1064	5	A-4911	20cm Black Heat Shrink Tubing 3.5mm	Tayda Electronics	Tayda	Austin Kucinski	\$0.10	\$0.50
1065	1	Generic	3D PLA Filament	Generic	Amazon	Nathan Huber	\$20.00	\$20.00
1066	1	TP-Link 8 Port	Ethernet Switch	TP-Link	Amazon	Nathan Huber	\$15.00	\$15.00
1067	1	SDN 5-24-100	24V Power Supply	Sola	Ebay	Nathan Huber	\$22.50	\$22.50
1068	1	Generic	USB Extension	Generic	Amazon	Nathan Huber	\$0.00	\$0.00
						University Funded:	\$107,288.90	\$107,288.90
						Personality Funded:	\$288.87	\$382.80
						Group:	\$288.87	\$382.80
						Total Cost:	\$107,577.77	\$107,671.70

Category	Estimated	Actual	Category	Estimated	Actual
Eye Tracking			Robotic Programming (Kuka & Fanuc)		
Market Research	10	10	Purchasing	15	22
Literature Review	10	8	Shipping/Install	10	70
Integration Research	10	10	Software Programming	50	45
Hardware Setup	25	15	Wire Assembly	10	5
Software Setup	25	40	Communication & IO	2	5
Troubleshooting	16	12	Initial Startup	10	4
Mount Construction	2	2	Debug	25	13
System Integration	16	10	Total:	122	164
Total:	114	107	PLC Programming		
Control Panel			Software Programming	30	16
Control Panel Hardware Design	20	5	Communication & IO	2	1.5
EOAT Panel Hardware Design	20	15	Debug	10	1.75
Control Panel Assembly	40	20	Total:	42	19.25
EOAT Panel Assembly	40	65	HMI Programming		
PCB Manufacturing(EOAT & Control)	15	30	Software Programming	25	16
Arduino Programming	20	25	Communication & IO	2	1.75
Debug	30	30	Debug	10	2
Total:	185	190	Total:	37	19.75
Presentations			Total Project		
Technical Design Reviews (Oral)	20	2	Total Hours:	580	512
Construct Poster	40	10	Labor Rate:	\$100	
Tech Expo	20	0	Total Cost:	\$58,000	\$51,200
Total:	80	12			

EOAT Panel

- Panelview C600
- Diverse Switches
- Arduino Feedback
- Stop Button
- PCB



Figure 3: EOAT Final Assembly

Control Panel

- PLC
- EtherCAT & Ethernet/IP
- Ethernet Switch
- Control HMI
- Power Supply



Figure 4: Control Panel

Head Pose Estimation (Hardware & Software)

- Logitech C920
 - 1080p at 30 frames per second
 - USB Communication
- OpenCV - Python
 - Computer vision library for Python and C++
 - Used for object recognition and tracking
 - Library: head-pose-estimation by lincolnhard



Figure 5: Face Tracking Video

Fanuc Robotics

- CR35-iA
 - Collaborative
 - Ethernet/IP Communication
 - 35kg Payload
 - 1.8m Reach
 - EOAT: Control Panel
 - DCS Safety

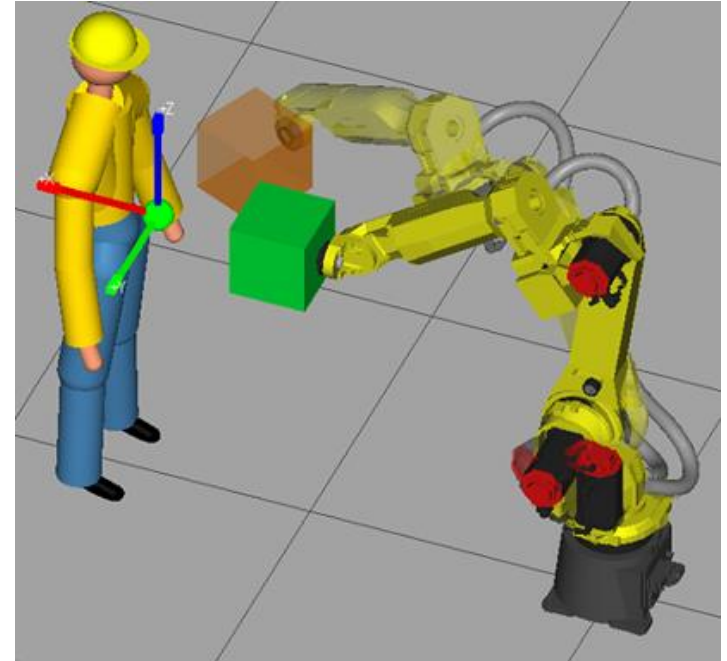


Figure 6: Fanuc Robot

Kuka Robotics

- LBR iiwa R820
 - Collaborative
 - Ethernet/IP Communication
 - 14kg Payload
 - 0.8m Reach
 - EOAT: Control Panel



Figure 7: Kuka Robot

HMI Screen

- C600 Allen Bradley HMI
 - Ethernet/IP Communication
 - User Interface Screen
 - Settings Screen
 - Control Panel Height
 - Radius

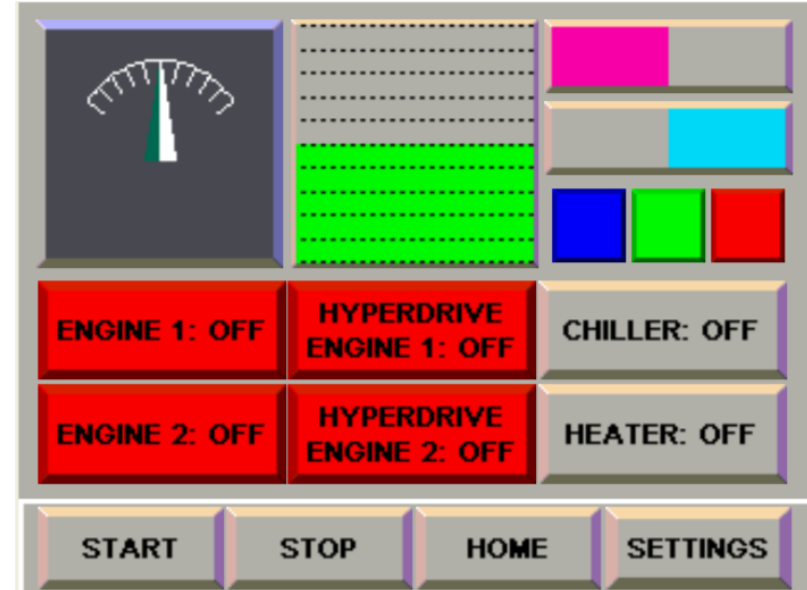


Figure 8: User Interface Screen (HMI)

PLC Controls

- Allen Bradley Compact PLC
 - Ethernet/IP Communication
 - 16 Digital IO
 - Logix 5000 Software
 - Interacts with the HMI
 - Receives data from Desktop by using the library Pycomm by Ruscito
 - Transmits data to robot

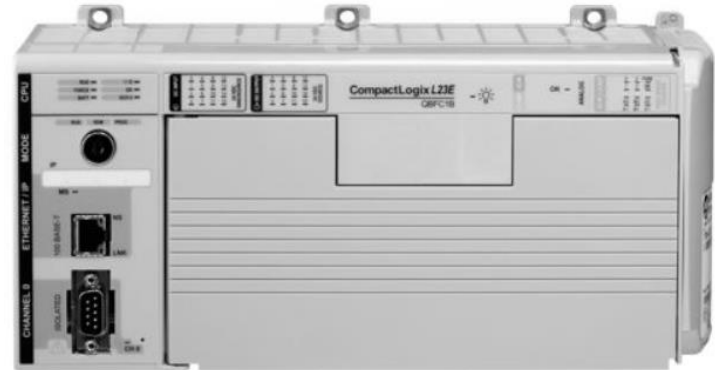


Figure 9: Allen Bradley PLC [2]

Future Plans

- Run user tests to achieve high accuracy within the current setup.
- Develop the Virtual Reality (VR) Component.
- Integrate VR and robotic control into one engaging interactive flight simulator.

Any Questions?

References:

1. Fly Away [Internet]. [cited 2018 October 27]. Available from:
<https://flyawaysimulation.com/news/4492/>
2. 1769-L23E-QB1B [Internet]. [cited 2018 October 27]. Available from:
<https://www.quicktimeonline.com/1769-L23E-QB1B>