

Team 512: Lockheed Martin Low-Cost HOTAS

EML 4551C



Robert Blount
Connor Chuppe
Robert Craig
Patrick Dixon



Team Introductions



Robert Blount
Systems Engineer



Connor Chuppe
Test Engineer



Robert Craig
Controls System Engineer

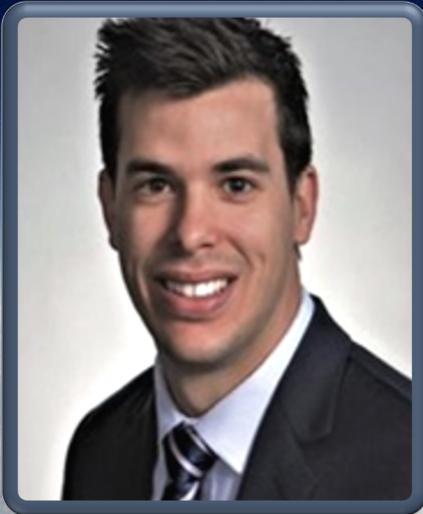


Patrick Dixon
*Mechatronics and
Geometric Design Engineer*

Connor Chuppe

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Sponsor and Advisor



Project Sponsor

Andrew Filiaut

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FSU College of Engineering



Project Adviser

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Professor at the
FAMU-FSU College
of Engineering

Connor Chuppe

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Project Objective



The objective of this project is to create a low-cost Hand-On Throttle and Stick (HOTAS) system to support the Pilot Training Devices (PTD) product line. The product will replicate the throttle control assembly and control stick of various fighter aircrafts.

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Updated Project Scope

Must use USB-A

Can pick one stick to resemble

Feedback is a nice feature but not required



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Key Goals and Functions



CREATE A LOW FIDELITY HOTAS WITH REASONABLE MANUFACTURING COSTS, AND REPAIRABILITY



BE ABLE TO FUNCTION WITH PREPAR3D SOFTWARE (LOCKHEED MARTIN SIMULATION SOFTWARE)



SHALL PROVIDE THE SAME FUNCTIONALITY AS CURRENT MODELS USED (BUGEYE F35 HOTAS, WRAITH SYSTEMS F35 HOTAS)



SHALL BE ABLE TO BE USED FOR DESKTOP TRAINING



BE ABLE TO COMMUNICATE WITH COMPUTER VIA STANDARD IO

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Targets-Metrics

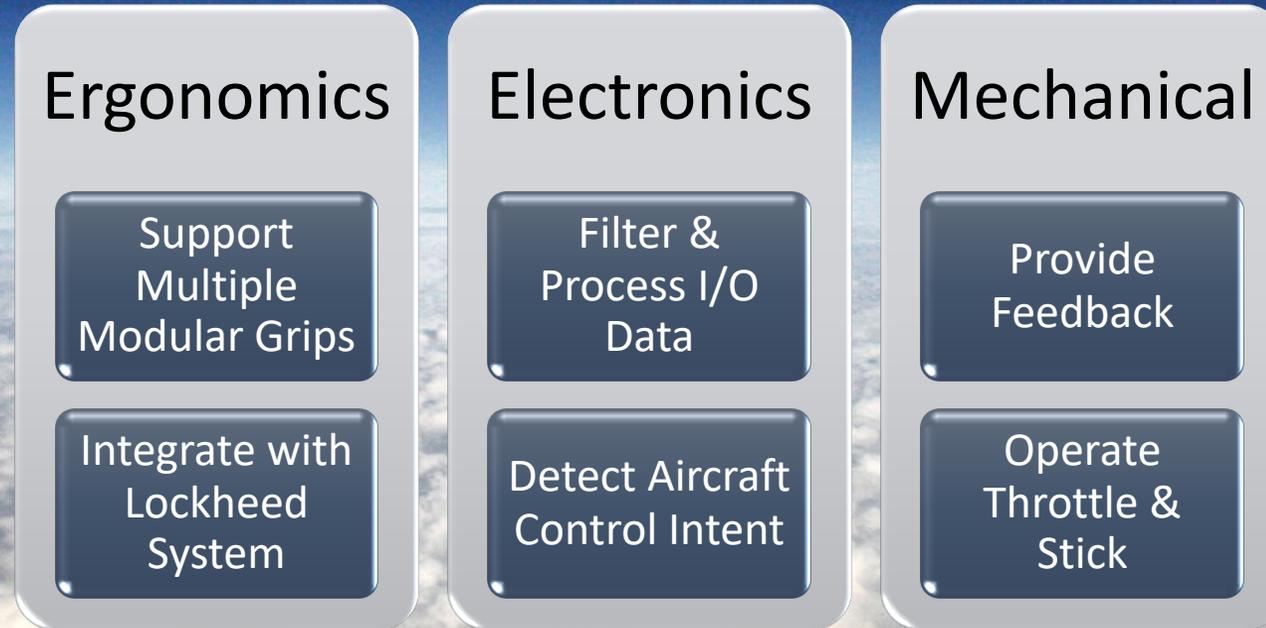
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Key Goals and Functions



Connor Chuppe



Targets and Metrics

Target and Metric for each function

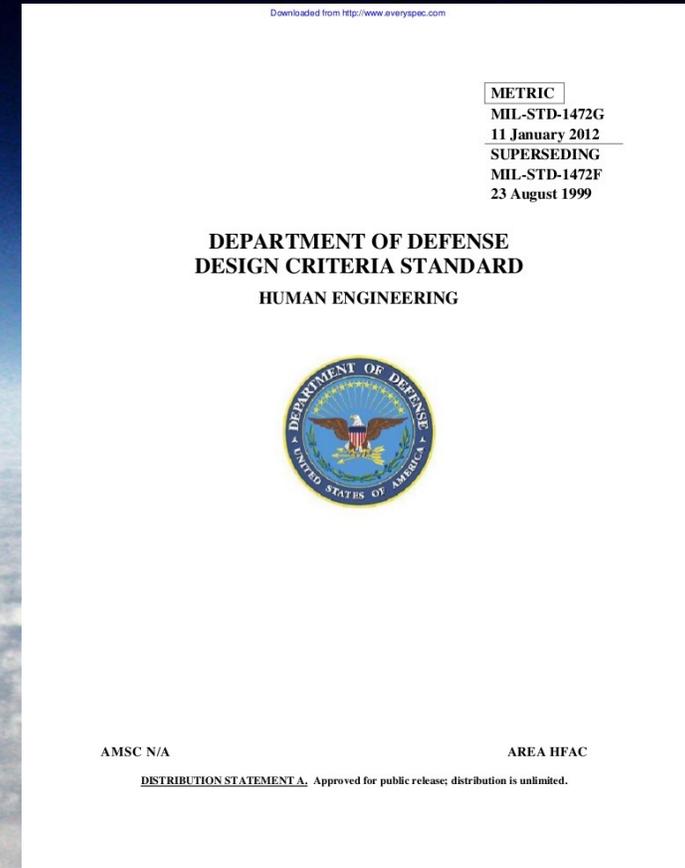
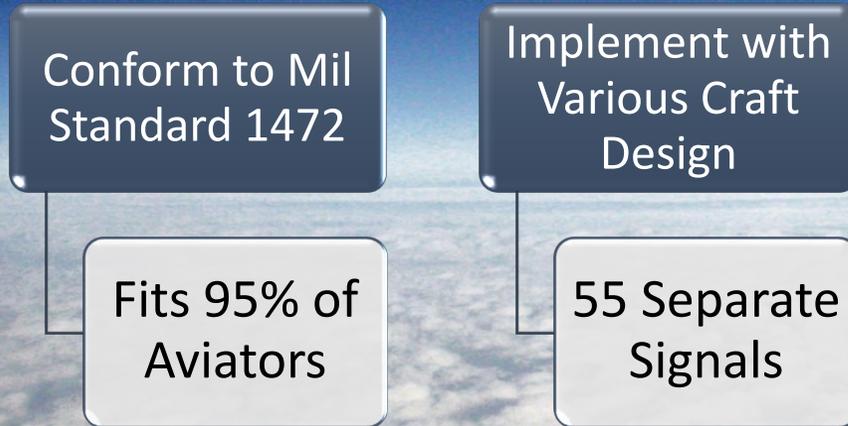
Targets and Metrics not directly stated as functions

Determination of critical targets and metrics

Critical Targets and Metrics		
Function	Target	Metric
Conform to MIL standard 1472	Fits 95% of aviators	Length, Diameter, Surface Area of throttle & stick
Integrate with Current Lockheed System	Yes	It works with the system
Implement with Various Craft Design	55 separate signals	Number of available signals
Filter and Process I/O Data	Filter noise, process data into appropriate signal type, fast Oms	Take in data input and output
Output Signals	transfer \leq 5Gbps of data to Prepar3d	transfer processed data through Output device to computer software
	\leq 10Gbps @ 250 MHz between throttle and stick units	data transfer size and rate
Detect Aircraft Control Intent	< 20 milli seconds	Input latency
Detect Signal Activation	< 20 milli seconds	Input latency
Operate Throttle, Stick and Buttons	Button can be depressed	Measure force required to depress button
	\pm 35 degrees for stick rotation	Angle of stick
	Throttle travels 6 " or rotates 65°	Distance throttle travels or angle of throttle

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Targets and Metrics



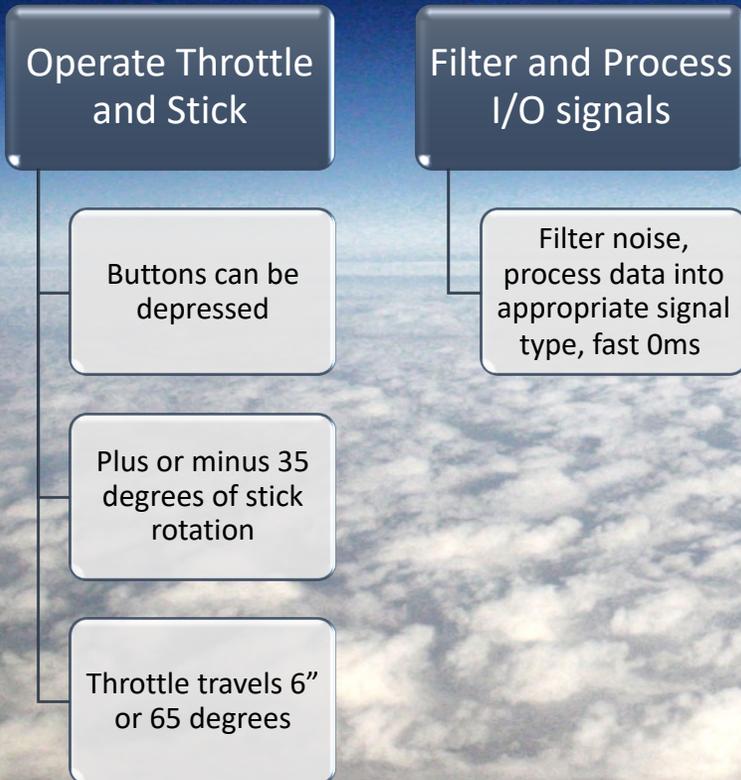
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Targets and Metrics



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Targets and Metrics



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Concept Generation



MORPHOLOGICAL CHART



BRAINSTORMING

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Morphological Chart

Subsystems	Fit	Form	Assembly	Process	Communication	Sense	Force	Throttle Displacement	Stick Displacement	Power	Mounting	Material
Generated Concepts	Thumbwheel Adjustment	Resemble F35	Separate Throttle & Stick	Arduino	USB-A		Torsional Spring	Sliding Throttle	Twistable Stick	Battery	Suction Cups	Plastics
	Pushbutton	Resemble F16	Single Unit Throttle & Stick	Custom Circuit Board	USB-B 3.0	Hall effect sensors	Stepper Motor	Rotating Throttle	Yaw on Throttle not Stick	From Computer	Clamp	Metals
	Toggle Switches	Resemble F22	Combined, but Modular for Separation	Raspberry Pi	USB-C	Potentiometer	DC Motor	Slotted Throttle			Velcro	Combination
	Isotonic Joystick	Threaded Grips for multiple crafts		Python Board	DV9	Motor DC					Increased Base Weight	Silicone
	combination from above	multiple Grip Covers for single Stick			Ethernet	Encoder					Mighty Mug Bottoms	Polymers
											Full Chair Mount	Fiber Materials

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Form



Resemble Sticks



Threaded Sticks



Multiple Grips

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Assembly



Separated Units



Solid Unit



Modular Units

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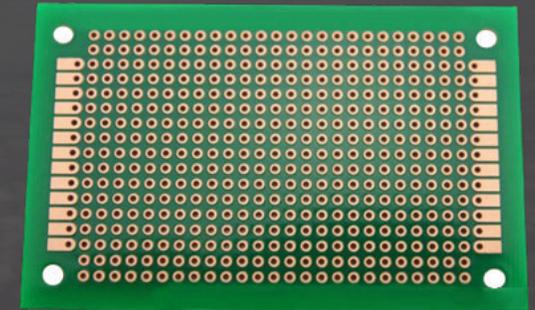
Process



Arduino Board



Python Board

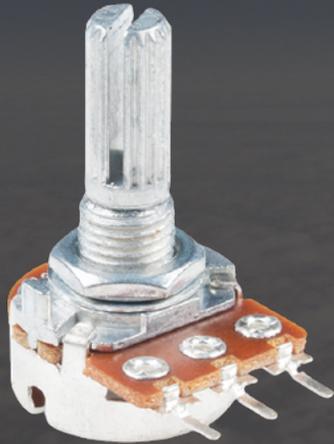


Custom PCB

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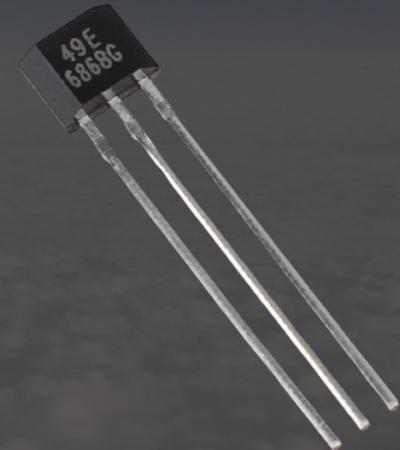
Sense



Potentiometer



DC Motor



Hall Effect

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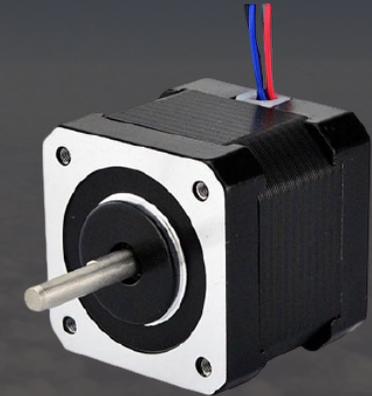
Force



Torsional Spring



DC Motor



Stepper Motor

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Throttle Displacement



Sliding Throttle



Rotating Throttle

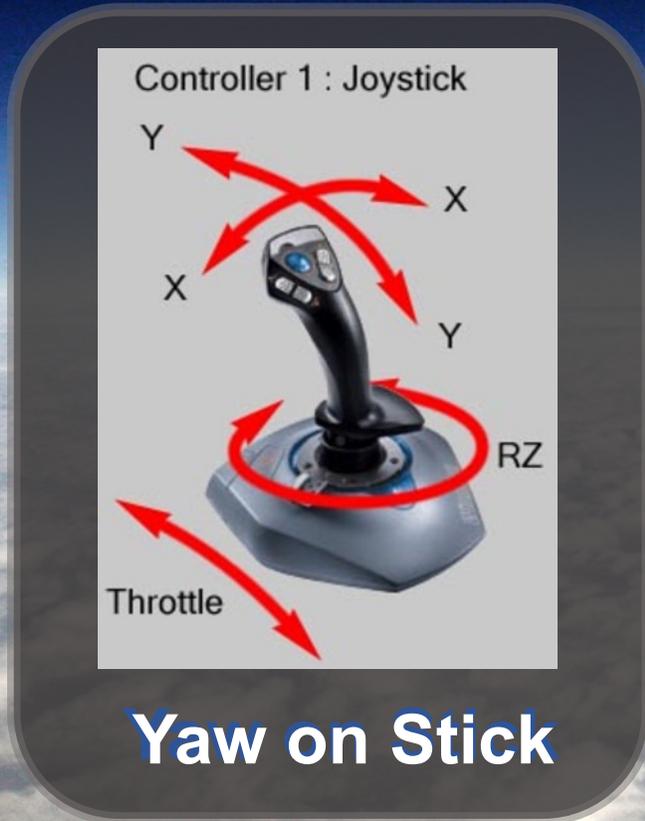


Slotted Throttle

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Stick Displacement



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Mounting



Suction Cups



Mighty Mug Bottoms



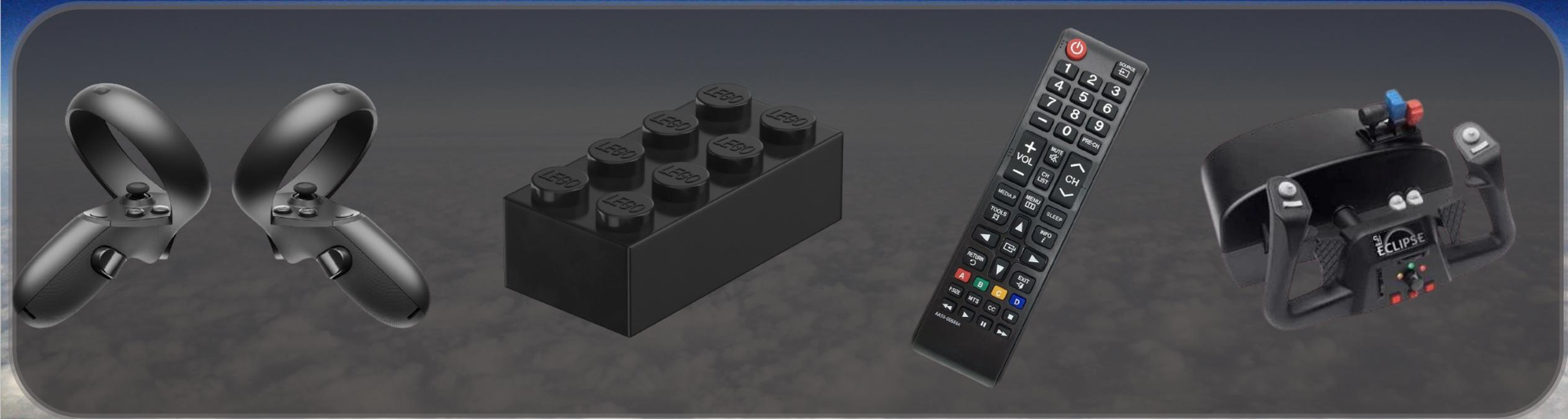
Chair Mount



Clamp

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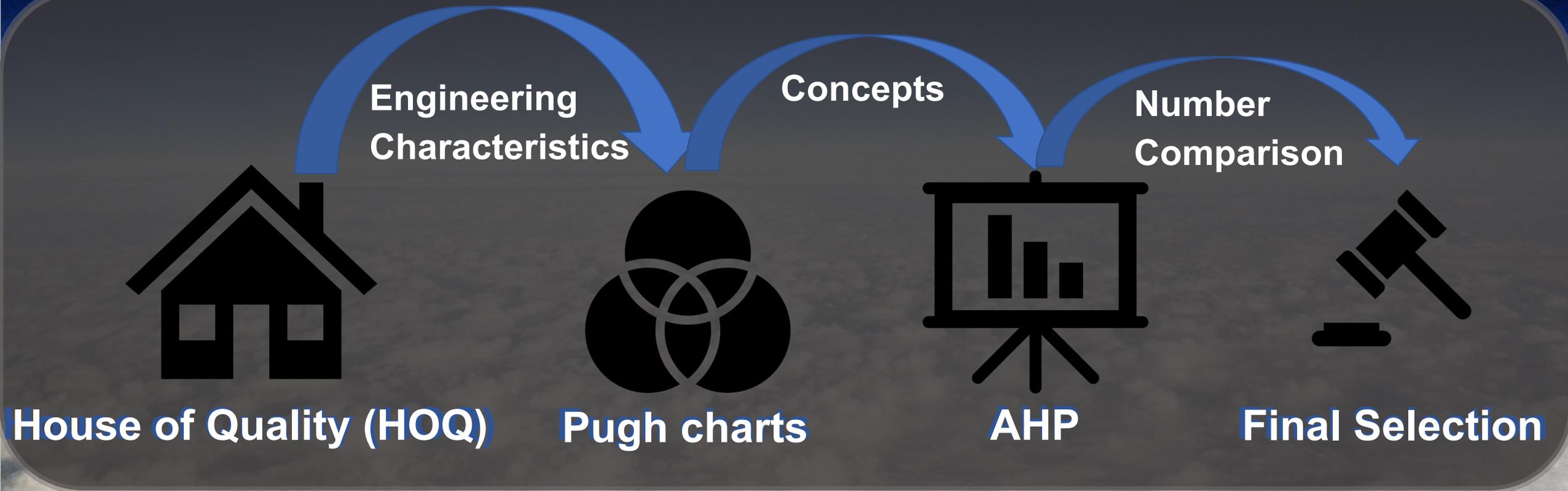
Brainstorming



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Concept Selection



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House of Quality

		Engineering Characteristics									
Improvement Direction		↑	↓	↓	↓	↑	↑	-	-	↑	↑
Units		Years	\$	n/a	ms	MHz	Mpa	lbs	n/a	lbsf	n/a
Customer requirements	Importance Weight Factor	Lifespan	Cost	Design Complexity	Latency/Transfer Speed	Frequency	Material Strength	Weight	Shape	Force	Repairability
Easily Repairable	1	1	3	3	1	0	3	0	9	0	9
Under \$4,000	3	0	9	9	3	3	3	3	1	3	3
Be able to Integrate With Lockheeds Software	4	0	1	1	3	3	0	0	0	0	0
Provide Feedback	1	0	3	1	3	1	3	1	1	9	1
Similar Functionality to Current Products	2	3	9	3	3	3	0	3	3	0	0
Raw Score	249	7	55	41	31	28	15	16	19	18	19
Relative Weight %		2.81	22.09	16.47	12.45	11.24	6.02	6.43	7.63	7.23	7.63
Rank Order		9	1	2	3	4	7	6	5	8	5

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Final Pugh Evaluation

Engineering Chars	Concepts					
	Concept 2	1	3	4	8	
Lifespan	Datum	S	-	S	S	
Cost		S	+	-	+	
Latency/Transfer Speed		S	S	S	S	
Frequency		S	-	S	S	
Material Strength		S	S	S	S	
Weight		S	S	+	S	
Shape		+	+	-	-	
Force		S	S	S	S	
Repairability		S	+	-	+	
Pluses			1	3	1	2
Minuses			0	2	3	1

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Analytical Hierarchy Process

Engineering Characteristics AHP	Weighted total
Lifespan	0.076
Cost	0.300
Transfer Speed/Latency	0.167
Frequency	0.156
Material Rigidity	0.034
Weight	0.026
Shape	0.025
Force	0.025
Repairability	0.193

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Analytical Hierarchy Process Outcome

AHP Outcomes	cost weighted totals	repairability weights	fr/res weighted total	concept totals	Normalized Totals	Ranking
Concept 1	0.055	0.104	0.413	0.572	0.1907	2
Concept 2	0.106	0.052	0.413	0.571	0.1904	3
Concept 3	0.623	0.676	0.127	1.426	0.4755	1
Concept 4	0.216	0.167	0.047	0.430	0.1434	4
totals	1.000	1.000	1.000	2.999	1.000	

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Final Selection



Threaded Sticks



Modular Units



Arduino Board



Potentiometer



Torsional Spring



Rotating Throttle



Yaw on Throttle



Suction Cups

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Future Work



Order
Components



Bill of
Materials



Prototyping



Initial Testing

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Important Takeaways



Iterative Process



Parts Pending



Functionality and Integrating with Lockheed's Software is Key

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Questions and Comments



Robert Blount
Connor Chuppe
Robert Craig
Patrick Dixon



When is the last time you pulled 9 G's at your desk



Robert Blount
Connor Chuppe
Robert Craig
Patrick Dixon

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Backup Slides

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targets and metrics backup

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Function	Target	Metric
Integrate with Current Lockheed System	Yes	It works with the system
Support Multiple Modular Grips	Variable per each stick	Major diameter and threading of mounting section for the stick
	1"-2"	Length of mounting section for the stick
	¼"-20	Pitch of the mounting threads for the stick
Integrate Buttons Within Specified Tolerances	±0.078-0.25in (2-6mm)	Distance button can be displaced
Input Feedback Signals	Receive signal for AOA, and craft speed to send to process into feedback	Receive data through USB to USB-A
Provide Feedback	1.12 ± 0.45 lbf (5 ± 2 N) of force	Provide an actuator force
This one and each below have no function to create a target and metric from	Less than \$4000 to manufacture	Cost in \$\$
	10 lbs. (45 N) ≤ weight ≤ 15 lbs. (67 N)	Weight
	Can be dropped from a height of 29" (73.66 cm) ± 1" (2.54 cm) at any orientation without mechanical failure	Drop height until failure
	At least 2 Years	Component Lifetime
	At least 5 years	Product Lifetime

Concept generation Backup

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Morphological Chart

Subsystems	Fit	Form	Assembly	Process	Communication	Sense	Force	Throttle Displacement	Stick Displacement	Power	Mounting	Material
Generated Concepts	Thumbwheel Adjustment	Resemble F35	Separate Throttle & Stick	Arduino	USB-A		Torsional Spring	Sliding Throttle	Twistable Stick	Battery	Suction Cups	Plastics
	Pushbutton	Resemble F16	Single Unit Throttle & Stick	Custom Circuit Board	USB-B 3.0	Hall effect sensors	Stepper Motor	Rotating Throttle	Yaw on Throttle not Stick	From Computer	Clamp	Metals
	Toggle Switches	Resemble F22	Combined, but Modular for Separation	Raspberry Pi	USB-C	Potentiometer	DC Motor	Slotted Throttle			Velcro	Combination
	Isotonic Joystick	Threaded Grips for multiple crafts		Python Board	DV9	Motor DC					Increased Base Weight	Silicone
	combination from above	multiple Grip Covers for single Stick			Ethernet	Encoder					Mighty Mug Bottoms	Polymers
											Full Chair Mount	Fiber Materials

Concepts	1	2	3	4	5
Fit	combination of buttons/switches	Isotonic Joystick	combination of buttons/switches	combination of buttons/switches	combination of buttons/switches
Form	Threaded Grips for multiple crafts	Threaded Grips for multiple crafts	Resemble F35	multiple Grip Covers for single Stick	Threaded Grips for multiple crafts
Assembly	combined, but modular for separation	Separate Throttle & Stick	combined, but modular for separation	Separate Throttle & Stick	combined, but modular for separation
Process	Arduino	Arduino	Arduino	Arduino	Arduino
Communication	USB-A	Ethernet	USB-A	DV9	USB-A
Sense	Hall effect sensors	Hall effect sensors	Hall effect sensors	Potentiometer	Encoder
Force	DC Motor	DC Motor	DC Motor	Torsional Spring	DC Motor
Throttle Displacement	Rotating Throttle	Sliding Throttle	Rotating Throttle	Rotating Throttle	Slotted Throttle
Stick Displacement	Twistable Stick	Yaw on Throttle not Stick	Twistable Stick	Yaw on Throttle not Stick	Twistable Stick
Power	from Computer	From Computer	from Computer	From Computer	From Computer
Mounting	Mighty Mug Bottoms	Increased Base Weight	Full Chair Mount	Suction Cups	Mighty Mug Bottoms
Material	Combination	Plastics	Combination	Plastics	Combination

Concepts	6	7	8	9	10
Fit	combination of buttons/switches	combination of buttons/switches	combination of buttons/switches	combination of buttons/switches	combination of buttons/switches
Form	Resemble F35	multiple Grip Covers for single Stick	Threaded Grips for multiple crafts	Threaded Grips for multiple crafts	Resemble F35
Assembly	combined, but modular for separation	Separate Throttle & Stick	combined, but modular for separation	Separate Throttle & Stick	combined, but modular for separation
Process	Arduino	Arduino	Arduino	Arduino	Arduino
Communication	USB-A	USB-A	USB-A	USB-A	USB-A
Sense	Encoder	Potentiometer	Hall effect sensors	Potentiometer	Hall effect sensors
Force	DC Motor	Torsional Spring	DC Motor	DC Motor	Torsional Spring
Throttle Displacement	Rotating Throttle	Sliding Throttle	Rotating Throttle	Rotating Throttle	Rotating Throttle
Stick Displacement	Twistable Stick	Yaw on Throttle not Stick	Twistable Stick	Yaw on Throttle not Stick	Twistable Stick
Power	From Computer	From Computer	From Computer	From Computer	From Computer
Mounting	Mighty Mug Bottoms	Suction Cups	Clamp	Full Chair Mount	Clamp
Material	Combination	Plastics	Plastics	Combination	Combination



Concepts	11	12	13	14	15
Fit	combination of buttons/switches	Push Button	combination	Toggle switches	Thumbwheel Adjustment
Form	Threaded Grips for multiple crafts	Resemble F35	Resemble F16	Resemble F35	multiple Grip Covers for single Stick
Assembly	combined, but modular for separation	Separate Throttle & Stick	Single Unit Throttle & Stick	Separate Throttle & Stick	Single Unit Throttle & Stick
Process	Arduino	Python Board	Python Board	Python Board	Python Board
Communication	USB-A	USB-A	USB-B 3.0	USB-C	USB-B 3.0
Sense	Encoder	DC Motor	DC Motor	DC Motor	Potentiometer
Force	DC Motor	Torsional Spring	DC Motor	Torsional Spring	Stepper Motor
Throttle Displacement	Sliding Throttle	Sliding Throttle	Sliding Throttle	Rotating Throttle	Slotted Throttle
Stick Displacement	Twistable Stick	Twistable Stick	yaw on Throttle not Stick	Twistable Stick	yaw on Throttle not Stick
Power	From Computer	from Computer	from Computer	Battery	from Computer
Mounting	Full Chair Mount	Clamp	suction cups	Velcro	increased base weight
Material	Combination	Silicone	Plastics	combination	Polymers

Concepts	16	17	18	19	20
Fit	Push Button	combination	Thumbwheel Adjustment	Toggle switches	combination
Form	Resemble F22	multiple Grip Covers for single Stick	Threaded Grips for multiple crafts	multiple Grip Covers for single Stick	Threaded Grips for multiple crafts
Assembly	Separate Throttle & Stick	Single Unit Throttle & Stick	Combined, but modular for separation	Combined, but modular for separation	Single Unit Throttle & Stick
Process	Python Board	Python Board	Python Board	Python Board	Python Board
Communication	USB-A	Ethernet	DV9	USB-C	USB-B 3.0
Sense	Encoder	Potentiometer	Hall effect sensors	Encoder	Hall effect sensors
Force	Torsional Spring	Stepper Motor	DC Motor	Stepper Motor	Torsional Spring
Throttle Displacement	Rotating Throttle	Slotted Throttle	Rotating Throttle	Sliding Throttle	Sliding Throttle
Stick Displacement	yaw on Throttle not Stick	Twistable Stick	yaw on Throttle not Stick	yaw on Throttle not Stick	Twistable Stick
Power	from Computer	Battery	Battery	from Computer	from Computer
Mounting	Full Chair Mount	increased base weight	Clamp	Mighty Mug Bottoms	suction cups
Material	Metals	combination	Metals	Fiber materials	Silicone



Concepts	26	27	28	29	30
Fit	Pushbutton	Isotonic Joystick	Thumbwheel Adjustment	Pushbutton	Thumbwheel Adjustment
Form	Resemble F16	Resemble F35	Resemble F22	multiple Grip Covers for single Stick	Resemble F22
Assembly	Single Unit Throttle & Stick	Separate Throttle & Stick	Separate Throttle & Stick	Combined, but Modular for Separation	Separate Throttle & Stick
Process	Raspberry Pi	Raspberry Pi	Raspberry Pi	Raspberry Pi	Raspberry Pi
Communication	DV9	Ethernet	USB-A	USB-B 3.0	Ethernet
Sense	Potentiometer	Hall effect sensors	Encoder	Hall effect sensors	Hall effect sensors
Force	Potentiometer	DC Motor	Stepper Motor	DC Motor	Stepper Motor
Throttle Displacement	Sliding Throttle	Rotating Throttle	Slotted Throttle	Sliding Throttle	Slotted Throttle
Stick Displacement	Twistable Stick	Yaw on Throttle not Stick	Twistable Stick	Yaw on Throttle not Stick	Twistable Stick
Power	Battery	From Computer	From Computer	From Computer	Battery
Mounting	Suction Cups	Full Chair Mount	Clamp	Velcro	Mighty Mug Bottoms
Material	Plastics	Metals	Combination	Fiber Materials	Silicone

Concepts	26	27	28	29	30
Fit	Pushbutton	Isotonic Joystick	Thumbwheel Adjustment	Pushbutton	Thumbwheel Adjustment
Form	Resemble F16	Resemble F35	Resemble F22	multiple Grip Covers for single Stick	Resemble F22
Assembly	Single Unit Throttle & Stick	Separate Throttle & Stick	Separate Throttle & Stick	Combined, but Modular for Separation	Separate Throttle & Stick
Process	Raspberry Pi	Raspberry Pi	Raspberry Pi	Raspberry Pi	Raspberry Pi
Communication	DV9	Ethernet	USB-A	USB-B 3.0	Ethernet
Sense	Potentiometer	Hall effect sensors	Encoder	Hall effect sensors	Hall effect sensors
Force	Potentiometer	DC Motor	Stepper Motor	DC Motor	Stepper Motor
Throttle Displacement	Sliding Throttle	Rotating Throttle	Slotted Throttle	Sliding Throttle	Slotted Throttle
Stick Displacement	Twistable Stick	Yaw on Throttle not Stick	Twistable Stick	Yaw on Throttle not Stick	Twistable Stick
Power	Battery	From Computer	From Computer	From Computer	Battery
Mounting	Suction Cups	Full Chair Mount	Clamp	Velcro	Mighty Mug Bottoms
Material	Plastics	Metals	Combination	Fiber Materials	Silicone



Concepts	31	32	33	34	35
Fit	combination from above	Thumbwheel Adjustment	combination from above	Pushbutton	combination from above
Form	Resemble F35	Resemble F35	Resemble F16	Resemble F22	Resemble F35
Assembly	Separate Throttle & Stick	Separate Throttle & Stick	Combined, but Modular for Separation	Combined, but Modular for Separation	Combined, but Modular for Separation
Process	Raspberry Pi	Custom Circuit Board	Custom Circuit Board	Custom Circuit Board	Custom Circuit Board
Communication	USB-C	USB-A	USB-A	USB-A	USB-A
Sense	Potentiometer	Encoders	Hall effect sensors	Motor DC	Motor DC
Force	Stepper Motor	Torsional Spring	Torsional Spring	Torsional Spring	Torsional Spring
Throttle Displacement	Rotating Throttle	Sliding Throttle	Sliding Throttle	Sliding Throttle	Rotating Throttle
Stick Displacement	Yaw on Throttle not Stick	Twistable Stick	Twistable Stick	Twistable Stick	Yaw on Throttle not Stick
Power	From Computer	Battery	Battery	From Computer	From Computer
Mounting	Suction Cups	Suction Cups	Increased Base Weight	Increased Base Weight	Clamp
Material	Plastics	Plastics	Combination	Combination	Metals

Concepts	36	37	38	39	40
Fit	Toggle Switches	Isotonic Joystick	combination from above	Toggle Switches	Toggle Switches
Form	Resemble F16	Resemble F22	Resemble F35	Resemble F16	Resemble F22
Assembly	Combined, but Modular for Separation	Combined, but Modular for Separation	Separate Throttle & Stick	Single Unit Throttle & Stick	Combined, but Modular for Separation
Process	Custom Circuit Board	Custom Circuit Board	Custom Circuit Board	Custom Circuit Board	Custom Circuit Board
Communication	DV9	USB-C	USB-A	Ethernet	USB-A
Sense	Potentiometer	Hall effect sensors	Hall effect sensors	Potentiometer	Encoder
Force	Stepper Motor	Stepper Motor	Torsional Spring	DC Motor	DC Motor
Throttle Displacement	Slotted Throttle	Slotted Throttle	Sliding Throttle	Slotted Throttle	Sliding Throttle
Stick Displacement	Twistable Stick	Twistable Stick	Twistable Stick	Yaw on Throttle not Stick	Yaw on Throttle not Stick
Power	From Computer	From Computer	From Computer	From Computer	From Computer
Mounting	Velcro	Velcro	Increased Base Weight	Increased Base Weight	Clamp
Material	Silicone	Silicone	Combination	Combination	Fiber Materials

Concepts	41	42	43	44	45
Fit	combination of buttons/switches	combination of buttons/switches	Isotonic Joystick	Push Button	Isotonic Joystick
Form	Threaded Grips for multiple crafts	multiple Grip Covers for single Stick	Threaded Grips for multiple crafts	Resemble F22	Threaded Grips for multiple crafts
Assembly	Separate Throttle & Stick	Separate Throttle & Stick	Combined, but modular for separation	Combined, but modular for separation	Separate Throttle & Stick
Process	Arduino	Arduino	Python Board	Python Board	Raspberry Pi
Communication	USB-A	USB-A	DV9	Ethernet	USB-B 3.0
Sense	Encoder	Potentiometer	Encoder	Potentiometer	Motor DC
Force	DC Motor	Torsional Spring	DC Motor	Torsional Spring	Torsional Spring
Throttle Displacement	Slotted Throttle	Rotating Throttle	Sliding Throttle	Slotted Throttle	Rotating Throttle
Stick Displacement	Twistable Stick	Yaw on Throttle not Stick	Twistable Stick	Twistable Stick	Yaw on Throttle not Stick
Power	From Computer	From Computer	Battery	Battery	From Computer
Mounting	Mighty Mug Bottoms	Clamp	Mighty Mug Bottoms	Clamp	Mighty Mug Bottoms
Material	Combination	Plastics	Fiber materials	Plastics	Polymers

Concepts	46	47	48	49	50
Fit	Isotonic Joystick	combination from above	Pushbutton	Isotonic Joystick	Pushbutton
Form	Resemble F16	Threaded Grips for multiple crafts	Resemble F22	Resemble F22	Resemble F22
Assembly	Single Unit Throttle & Stick	Separate Throttle & Stick	Single Unit Throttle & Stick	Combined, but Modular for Separation	Separate Throttle & Stick
Process	Raspberry Pi	Custom Circuit Board	Custom Circuit Board	Custom Circuit Board	Custom Circuit Board
Communication	USB-A	USB-B 3.0	DV9	USB-C	USB-C
Sense	Hall effect sensors	Motor DC	Potentiometer	Motor DC	Encoder
Force	DC Motor	Torsional Spring	Torsional Spring	DC Motor	Torsional Spring
Throttle Displacement	Sliding Throttle	Rotating Throttle	Rotating Throttle	Rotating Throttle	Slotted Throttle
Stick Displacement	Yaw on Throttle not Stick	Yaw on Throttle not Stick	Yaw on Throttle not Stick	Yaw on Throttle not Stick	Yaw on Throttle not Stick
Power	Battery	From Computer	From Computer	Battery	From Computer
Mounting	Velcro	Increased Base Weight	Clamp	Clamp	Increased Base Weight
Material	Metals	Silicone	Silicone	Fiber Materials	Combination

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- The throttle base has buttons but not on the throttle itself. The base for the stick has no buttons but the stick itself has all the necessary buttons. Separate base for throttle and stick
- The throttle base doesn't have buttons, all throttle buttons are on the throttle itself. Stick base has buttons and not on the stick itself. Separate base for throttle and stick
- The base has all the buttons on it and no buttons on the throttle or stick. Single base for throttle and stick
- The HOTAS becomes just a stick with throttle functionality, in example the stick rotates in 3 axis and move along one.
- Throttle with a detent to distinguish between various engine stages.
- Use lights with heat camera to determine location and placement of hands to operate the hotas, without a physical throttle or stick, just bases for either main subsystem.
- Use only COTS (Commercially off the Shelf) parts to make up the buttons
- Bee-Hive resembling throttle and stick to save money on amount of material
- 3-D print all the buttons, stick and throttle
- Disassemble a working keyboard to recreate a HOTAS by using switches and keys along with the rollers and sliders on some keyboards.

- Using a 3-d scanner and appropriate tech create the one stick and throttle to rule them all (like the one ring form lord of the rings), with functionality in key locations for each of the operable crafts chosen
- Destroy an existing HOTAS of low fidelity to create a new shell and reuse most of their electronics and components.
- Entire desk is the HOTAS, the stick and throttle built into the desk surface as well as all the buttons and switches
- Haptic HOTAS, gloves on the hand that recognize hand positions in space to detect control intent
- Chair with throttle and stick built into the armrests
- HOTAS that reacts to neural signals to detect aircraft intent
- Base made with foam core
- Have dual throttle that controls yaw when pushed in opposite directions
- Stick made from a used car gear shift
- Disassemble a computer mouse to use the scroll wheel and left and right click buttons

- Use a ball joint for the stick with variable resistance in all directions to detect the control intent.
- Electric signal could then be sent through the stick to sense the orientation of the stick
- Base housing made of LEGO's, could be painted and glued together to form a rigid structure
- Printed circuit boards to direct the signals instead of a lot of wires
- Oculus rift set up. Doesn't have to actually be virtual reality but both the stick and throttle could be floating controllers not mounted to a base and the user just has to manipulate the controllers in mid air
- Breaking down and using a video game controllers' components and board to provide some functionalities of the HOTAS.
- Stick that doesn't move but interprets the amount of force being applied
- Throttle that is able to be detached and replaced with a different style
- Buttons that sense force but don't physically depress

- Buttons that are rubber similar to a tv remote
- Stick base bolted to floor
- A yoke(flight steering wheel) with the HOTAS implemented into it, so that the right side has the stick with operable functions and the left side has the throttle with rotating functionality.
- Mirror the Atari 2600 system Joystick
- Replicate actual assembly of current military aircraft
- Glove like HOTAS controlled by hand gestures
- Use radio waves as a form of communication between the stick and throttle
- Strain gauges to sense input
- Filter the signals using various hardware rather than coding
- Foldable HOTAS with a hinge on where the shaft connects to the base for transformational purposes

- Instead of having a base to mount to the desk, you have it attached via a wrap around on your legs
- All leg functional HOTAS
- Bluetooth/WIFI HOTAS
- Magnetic interchangeable stick
- Tripod style base for stick instead of rectangular
- Ferro-magnetic fluid to create the different sticks to then operate with similar control
- Altering the shape of the HOTAS to conform to various sticks by changing an active frequency to be applied through sound waves.
- GPS sensor to determine pitch roll yaw of the HOTAS and throttle
- Use a belt system to actuate the throttle. There would theoretically be no backlash in the system
- 4-bar linkage mechanism for the throttle, it could either be a coupler or an output link
- Have the HOTAS in a booth and use lidar to detect the orientation of the stick and/or throttle
- Snap-fit throttle. If a material is pliable enough, then the end of the throttle it could be deformed to fit into a holder. Can work by either applying this concept to the throttle/stick or to the holder it mates into.

Introduction > Overview > Targets-Metrics > Concept Generation > Concept Selection > Final Selection > Review

HOQ backup

Customer Requirement	1	2	3	4	5	Total
Easily Repairable	–	0	0	1	0	1
Under \$4,000	1	–	0	1	1	3
Be able to integrate with Lockheeds software	1	1		1	1	4
Provide Feedback	0	0	0	–	0	0
Similar Functionality to Current Products	1	0	0	1	–	2
Total	3	1	0	4	2	

		Engineering Characteristics									
Improvement Direction		↑	↓	↓	↓	↑	↑	–	–	↑	↑
Units		Years	\$	n/a	ms	MHz	Mpa	lbs	n/a	lbsf	n/a
Customer requirements	Importance Weight Factor	Lifespan	Cost	Design Complexity	Latency/Transfer Speed	Frequency	Material Strength	Weight	Shape	Force	Repairability
Easily Repairable	1	1	3	3	1	0	3	0	9	0	9
Under \$4,000	3	0	9	9	3	3	3	3	1	3	3
Be able to Integrate With Lockheeds Software	4	0	1	1	3	3	0	0	0	0	0
Provide Feedback	1	0	3	1	3	1	3	1	1	9	1
Similar Functionality to Current Products	2	3	9	3	3	3	0	3	3	0	0
Raw Score	249	7	55	41	31	28	15	16	19	18	19
Relative Weight %		2.81	22.09	16.47	12.45	11.24	6.02	6.43	7.63	7.23	7.63
Rank Order		9	1	2	3	4	7	6	5	8	5

pugh charts backup

		Concepts								
Engineering Chars	Wraith Systems	1	2	3	4	5	6	7	8	
Lifespan	Datum	+	+	+	+	+	+	+	+	
Cost		+	+	+	+	+	+	+	+	
Latency/Transfer Speed		-	-	-	-	-	-	-	-	
Frequency		-	-	-	-	-	-	-	-	
Material Strength		-	-	-	-	-	-	-	-	
Weight		-	-	-	-	-	-	-	-	
Shape		-	-	-	-	-	-	-	-	
Force		-	-	-	-	-	-	-	-	
Repairability		+	+	+	+	+	+	+	+	
Pluses			3	3	3	3	3	3	3	3
Minuses			6	6	6	6	6	6	6	6

pugh charts backup

	Concepts							
Engineering Chars	Concept 1	2	3	4	5	6	7	8
Lifespan	Datum	S	-	S	-	S	S	S
Cost		-	+	-	+	-	+	+
Latency/Transfer Speed		S	-	S	S	S	-	S
Frequency		S	S	S	S	S	S	S
Material Strength		S	S	S	-	S	-	S
Weight		S	S	+	-	S	-	S
Shape		S	+	-	S	S	S	-
Force		S	S	S	-	+	-	S
Repairability		S	+	-	+	-	S	+
Pluses		0	4	1	2	1	1	2
Minuses		1	2	3	4	2	4	1

pugh charts backup

		Concepts					
Engineering Chars	Concept 3	1	2	4	5	8	
Lifespan	Datum	+	S	S	-	S	
Cost		-	+	-	+	+	
Latency/Transfer Speed		+	+	S	S	S	
Frequency		S	S	S	S	S	
Material Strength		S	S	S	-	S	
Weight		S	S	+	-	S	
Shape		-	S	-	S	-	
Force		-	-	S	-	S	
Repairability		-	-	-	+	+	
Pluses			2	2	1	2	2
Minuses			4	1	3	4	1

pugh charts backup

		Concepts				
Engineering Chars	Concept 2	1	3	4	8	
Lifespan	Datum	S	-	S	S	
Cost		S	+	-	+	
Latency/Transfer Speed		S	S	S	S	
Frequency		S	-	S	S	
Material Strength		S	S	S	S	
Weight		S	S	+	S	
Shape		+	+	-	-	
Force		S	S	S	S	
Repairability		S	+	-	+	
Pluses			1	3	1	2
Minuses			0	2	3	1

AHP charts backup

Engineering Characteristics in AHP	LifeSpan	Cost	Transfer Speed/Latency	Frequency	Material Rigidity	Weight	Shape	Force	Repeatability
LifeSpan	1	0.54	0.60	0.52	0.59	0.50	0.57	0.56	0.54
Cost	0.54	1	0.59	0.58	0.51	0.57	0.50	0.53	0.50
Transfer Speed/Latency	0.60	0.59	1	0.52	0.56	0.50	0.53	0.50	0.50
Frequency	0.52	0.58	0.52	1	0.53	0.50	0.50	0.50	0.50
Material Rigidity	0.59	0.51	0.56	0.53	1	0.50	0.50	0.50	0.50
Weight	0.50	0.57	0.50	0.50	0.50	1	0.50	0.50	0.50
Shape	0.57	0.50	0.53	0.50	0.50	0.50	1	0.50	0.50
Force	0.56	0.53	0.50	0.50	0.50	0.50	0.50	1	0.50
Repeatability	0.54	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1

Engineering Characteristics in AHP	LifeSpan	Cost	Transfer Speed/Latency	Frequency	Material Rigidity	Weight	Shape	Force	Repeatability
LifeSpan	0.185	0.064	0.060	0.052	0.059	0.050	0.057	0.056	0.054
Cost	0.066	0.177	0.159	0.188	0.151	0.157	0.150	0.151	0.168
Transfer Speed/Latency	0.065	0.126	0.120	0.052	0.066	0.060	0.063	0.079	0.060
Frequency	0.055	0.126	0.159	0.096	0.105	0.143	0.143	0.179	0.025
Material Rigidity	0.058	0.064	0.064	0.059	0.059	0.029	0.066	0.026	0.058
Weight	0.058	0.062	0.057	0.059	0.059	0.029	0.029	0.026	0.058
Shape	0.058	0.064	0.064	0.059	0.051	0.029	0.029	0.026	0.055
Force	0.058	0.062	0.057	0.054	0.059	0.029	0.029	0.026	0.054
Repeatability	0.055	0.126	0.060	0.080	0.051	0.060	0.063	0.051	0.133
Total	1	1	1	1	1	1	1	1	1

Weighted total	Weighted sum	Consistency vector	average consistency	10.0820
0.076	0.716	9.433	n value	9
0.300	3.240	10.806	Consistency index	0.1353
0.167	1.770	10.628	Ri (lookup value (n))	1.45
0.156	1.615	10.375	Consistency Ratio	0.0933
0.034	0.319	9.376		
0.026	0.250	9.786		
0.025	0.243	9.792		
0.025	0.235	9.589		
0.193	2.116	10.953		

AHP charts backup

Cost AHP	Concept 1	Concept 2	Concept 3	Concept 4
Concept 1	1	1/3	1/7	1/5
Concept 2	3	1	1/7	1/3
Concept 3	7	7	1	5
Concept 4	5	3	1/5	1
Total	16.00	11.33	1.49	6.53

Cost N AHP	Concept 1	Concept 2	Concept 3	Concept 4
Concept 1	0.063	0.029	0.096	0.031
Concept 2	0.188	0.088	0.096	0.051
Concept 3	0.438	0.618	0.673	0.765
Concept 4	0.313	0.265	0.135	0.153
Total	1	1	1	1

weighted total	weighted sum total	consistency vector	average consistency	4.2457
0.055	0.222	4.065	n value lookup	4
0.106	0.431	4.075	Consistency Index	0.0819
0.623	2.827	4.535	Random index value	0.89
0.216	0.931	4.308	Consistency Ratio	0.0920
1				

AHP charts backup

Repairability AHP	Concept 1	Concept 2	Concept 3	Concept 4
Concept 1	1	3 1/33	1/7	1/3
Concept 2	1/3	1	1/9	1/3
Concept 3	7	9	1	7 2/71
Concept 4	3	3	1/7	1
Total	11.33	16.03	1.40	8.71

Repairability N AHP	Concept 1	Concept 2	Concept 3	Concept 4
Concept 1	0.088	0.189	0.102	0.038
Concept 2	0.029	0.062	0.080	0.038
Concept 3	0.618	0.561	0.716	0.809
Concept 4	0.265	0.187	0.102	0.115
Total	1	1	1	1

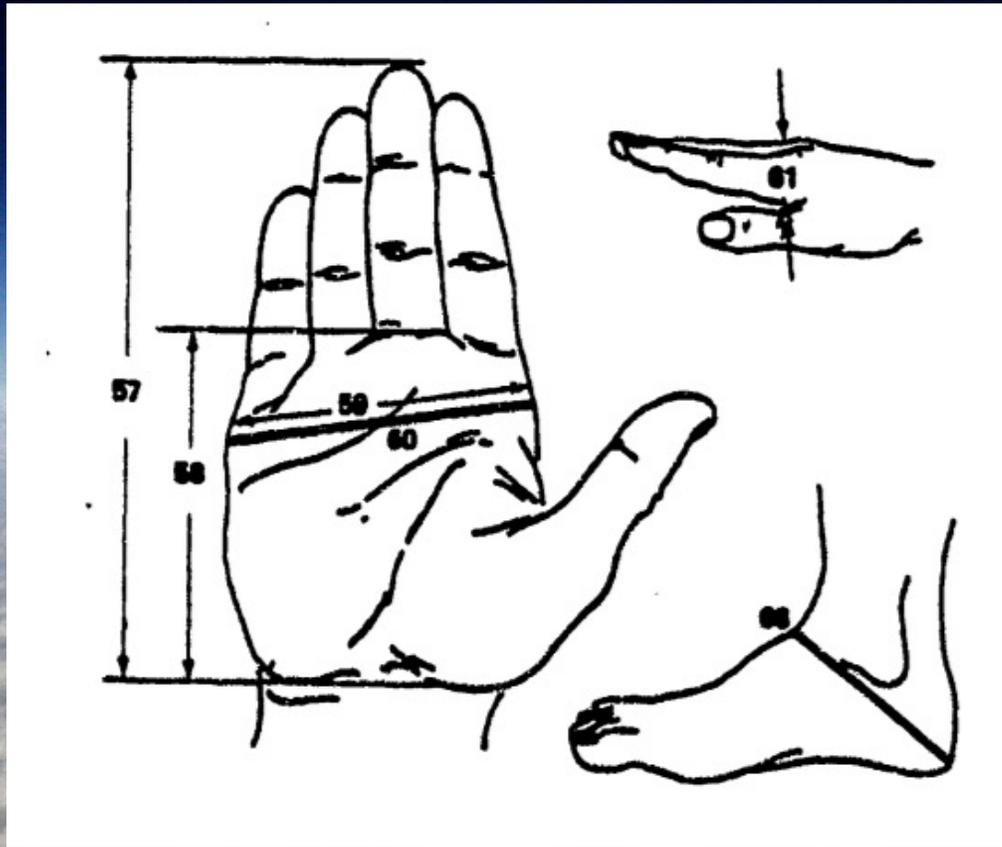
weighted total	weighted sum total	consistency vector	average consistency	4.2607
0.104	0.415	3.976	n value lookup	4
0.052	0.218	4.158	Consistency Index	0.0869
0.676	3.055	4.519	Random index value	0.89
0.167	0.734	4.390	Consistency Ratio	0.0976
1				

AHP charts backup

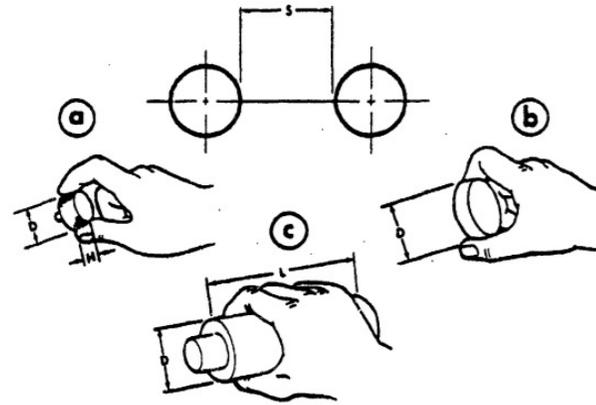
Frequency(resolution) AHP	Concept 1	Concept 2	Concept 3	Concept 4
Concept 1	1	1	5	2 3/71
Concept 2	1	1	5	2 3/71
Concept 3	1/5	1/5	1	5
Concept 4	1/7	1/7	1/5	1
Total	2.94	2.94	11.20	20.00

Frequency(resolution) N AHP	Concept 1	Concept 2	Concept 3	Concept 4
Concept 1	0.427	0.427	0.446	0.351
Concept 2	0.427	0.427	0.446	0.351
Concept 3	0.085	0.085	0.089	0.249
Concept 4	0.061	0.061	0.018	0.050
Total	1	1	1	1

weighted total	weighted sum total	consistency vector	average consistency	4.2172
0.413	1.794	4.347	n value lookup	4
0.413	1.794	4.347	Consistency Index	0.0724
0.127	0.528	4.153	Random index value	0.89
0.047	0.190	4.021	Consistency Ratio	0.0813
1				



	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
HAND DIMENSIONS						
57 HAND LENGTH	17.4	17.7	16.1	20.7	20.7	20.0
58 PALM LENGTH	9.8	10.0	9.0	11.7	11.9	10.8
59 HAND BREADTH	8.1	8.2	6.9	9.7	9.7	8.5
60 HAND CIRCUMFERENCE	19.5	19.6	16.8	23.6	23.1	19.9
61 HAND THICKNESS		2.4			3.5	
FOOT DIMENSIONS						
62 FOOT LENGTH	24.5	24.4	22.2	29.0	29.0	26.5
63 INSTEP LENGTH	17.7	17.5	16.3	21.7	21.4	19.8
64 FOOT BREADTH	9.0	9.0	8.0	10.9	11.6	9.8
65 FOOT CIRCUMFERENCE	22.5	22.6	20.8	27.4	27.0	24.5
66 HEEL-ANKLE CIRCUMFERENCE	31.3	30.7	28.5	37.0	36.3	33.3
	PERCENTILE VALUES IN INCHES					
HAND DIMENSIONS						
57 HAND LENGTH	6.85	6.98	6.32	8.13	8.14	7.89
58 PALM LENGTH	3.77	3.92	3.56	4.61	4.69	4.24
59 HAND BREADTH	3.20	3.22	2.72	3.83	3.80	3.33
60 HAND CIRCUMFERENCE	7.68	7.71	6.62	9.28	9.11	7.82
61 HAND THICKNESS		0.96			1.37	
FOOT DIMENSIONS						
62 FOOT LENGTH	9.65	9.62	8.74	11.41	11.42	10.42
63 INSTEP LENGTH	6.97	6.89	6.41	8.54	8.42	7.70
64 FOOT BREADTH	3.53	3.54	3.16	4.29	4.58	3.84
65 FOOT CIRCUMFERENCE	8.86	8.91	8.17	10.79	10.62	9.65
66 HEEL-ANGLE CIRCUMFERENCE	12.32	12.08	11.21	14.57	14.30	13.11



DIMENSIONS					
	a Fingertip Grasp		b Thumb and Finger Encircled	c Palm Grasp	
	H Height	D Diameter	D Diameter	D Diameter	L Length
Minimum	13 mm (1/2 in.)	10 mm (3/8 in.)	25 mm (1 in.)	38 mm (1-1/2 in.)	75 mm (3 in.)
Maximum	25 mm (1 in.)	100 mm (4 in.)	75 mm (3 in.)	75 mm (3 in.)	.
TORQUE			SEPARATION		
	.	**	S One Hand Individually	S Two Hands Simultaneously	
Minimum	.	.	25 mm (1 in.)	50 mm (2 in.)	
Optimum	.	.	50 mm (2 in.)	125 mm (5 in.)	
Maximum	32 mN-m (=1/2 in.-oz.)	42 mN-m (5 in.-oz.)	.	.	

*To and including 25 mm (1.0 in.) diameter knobs
 **Greater than 25 mm (1.0 in.) diameter knobs

FIGURE 7. KNOBS