Statistical Analysis and Planning for Manned Space Exploration Internship

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Where I Spent the Summer

NASA

Johnson Space Center

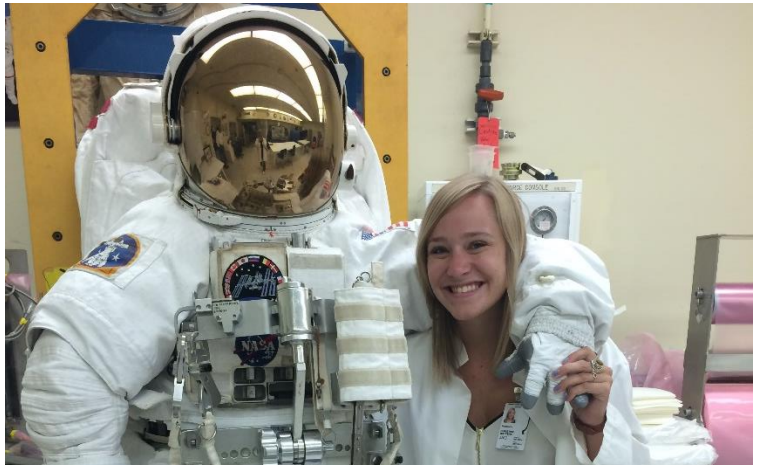
Engineering Directorate

Crew and Thermal Systems Division

EC2: Design and Analysis Branch

Advanced Space Exploration Logistics Reduction

Advanced Clothing System



Crew Clothing Care

Background

- There is no system on the ISS for cleaning clothing.
- Clothing are taking up to much mass on the resupply launches and resupply launches will not exist for Mars exploration.
- Clean clothing will help crew members live in a more hygienic and sustainable environment which is also important to mental health and morale.

Crew Clothing Care

Considerations

- Ozone
  - How is it used in sanitation?
  - What are the harmful effects?
- Water and Hydrogen Peroxide
  - How much is to much?
  - How can it be applied?
- Fabric
  - Cotton, Polyester – Currently worn by astronauts
  - Modacrylic, Wool – Being tested for long duration missions.

Crew Clothing Care

Procedure

- Soil eighty 2”x2” swatches of fabrics with three drops of fish sauce and let sit for 24 hours. Weigh samples.
- Spray selected samples with two sprays of hydrogen peroxide and place in the ozone for 30 minutes. Repeat process for selected samples.
- Place samples in the washer for two, 19 minute spin and dry cycles. Place samples in the dryer for two, 13 minute quick dry, no heat cycles. Weigh samples.

Crew Clothing Care

Data Collection

- Thirteen panel members were recruited to smell and look at an unsoiled swatch of fabric and then compare the treated samples.
- Panelists did not know if and how they were cleaned.
- They came for 10 sessions because we limited the amount of coupons they could smell at one time to 8.

W	None	Faint	Strong
Smell			
Stain			

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Table of Smell by Fabric					
Smell	Fabric				
Frequency Expected Percent	C	M	P	W	Total
Strong	127 93 12.21	144 93 13.85	80 93 7.69	21 93 2.02	372 35.77
Faint	108 115.25 10.38	96 115.25 9.23	132 115.25 12.69	125 115.25 12.02	461 44.33
None	25 51.75 2.40	20 51.75 1.92	48 51.75 4.62	114 51.75 10.96	207 19.90
Total	260 25.00	260 25.00	260 25.00	260 25.00	1040 100.00

Table of Smell by Cycles				
Smell	Cycles			
Frequency Expected Percent	1	2	0	Total
Strong	192 167.4 18.46	139 167.4 13.37	41 37.2 3.94	372 35.77
Faint	196 207.45 18.85	221 207.45 21.25	44 46.1 4.23	461 44.33
None	80 93.15 7.69	108 93.15 10.38	19 20.7 1.83	207 19.90
Total	468 45.00	468 45.00	104 10.00	1040 100.00

Crew Clothing Care

Olfactory Data

- Since our variable smell is ordinal we model it using logistic regression with a cumulative logit function.

- This model will regress the smell variable against the fabrics and number of cycles, including panelist as a random effect.

Crew Clothing Care

Olfactory Data

- Type 3 tests are testing if the main effects contribute to the model.

- The number of cycles and the type of fabric are significant in weight change.

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fabric	3	1021	70.40	<.0001
cycles	2	1021	8.98	0.0001

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Olfactory Data

- When compared to cotton,
  - Modacrylic is just as likely to get a smell response of none.
  - Polyester is 2.4 times more likely to get a smell response of none.
  - Wool is 10 times more likely to get a smell response of none.

- When compared to zero cycles,
  - One cycle is just as likely to get a smell response of none.
  - Two cycles is 1.64 times more likely to get a smell response of none.

Odds Ratio Estimates							
Fabric	cycles	Fabric	cycles	Estimate	DF	95% Confidence Limits	
M		C		0.746	1021	0.527	1.055
P		C		2.377	1021	1.692	3.338
W		C		9.891	1021	6.846	14.289
	1		0	0.963	1021	0.627	1.477
	2		0	1.638	1021	1.068	2.511

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Table of Stain by Fabric					
Stain	Fabric				
Frequency Expected Percent	C	M	P	W	Total
Strong	16 57.555 1.54	158 57.555 15.21	22 57.334 2.12	34 57.555 3.27	230 22.14
Faint	74 80.577 7.12	52 80.577 5.00	67 80.268 6.45	129 80.577 12.42	322 30.99
None	170 121.87 16.36	50 121.87 4.81	170 121.4 16.36	97 121.87 9.34	487 46.87
Total	260 25.02	260 25.02	259 24.93	260 25.02	1039 100.00
Frequency Missing = 1					

Table of Stain by Cycles				
Stain	Cycles			
Frequency Expected Percent	1	2	0	Total
Strong	92 103.6 8.85	70 103.38 6.74	68 23.022 6.54	230 22.14
Faint	144 145.04 13.86	156 144.73 15.01	22 32.231 2.12	322 30.99
None	232 219.36 22.33	241 218.89 23.20	14 48.747 1.35	487 46.87
Total	468 45.04	467 44.95	104 10.01	1039 100.00
Frequency Missing = 1				

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Stain Data

- Again I used logistic regression with a cumulative logit function to model the stain data because this is an ordinal response.

- This model will regress the stain variable against the fabrics and number of cycles, including panelist as a random effect.

Crew Clothing Care

Stain Data

This gives us the same conclusion as the smell data did, that both the number of cycles and the type of fabric are significant in weight change.

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
fabric	3	1020	92.14	<.0001
cycles	2	1020	63.73	<.0001

Crew Clothing Care

Stain Data

- When compared to cotton,
  - Polyester is just as like to get a smell response of none.
  - Modacylic is 0.045 times more likely to get a smell response of none.
  - Wool is 0.3 times more likely to get a smell response of none.

- When compared to zero cycles,
  - One cycle is 13.45 times more likely to get a smell response of none.
  - Two cycles is 16.9 times more likely to get a smell response of none.

Odds Ratio Estimates							
Fabric	cycles	Fabric	cycles	Estimate	DF	95% Confidence Limits	
P		C		0.894	1020	0.614	1.302
M		C		0.045	1020	0.030	0.067
W		C		0.298	1020	0.209	0.425
	2		0	16.917	1020	10.291	27.808
	1		0	13.450	1020	8.246	21.937

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Weight Data

- The new variable weight change was computed by subtracting the weight after the treatment from the weight before the treatment.
- In two cases the wool absorbed more hydrogen peroxide than it released causing for a negative weight change (weight gain).

Fabric	mean	std	min	max	meadian
c	0.07252	0.038623	0.0000	0.1317	0.06895
m	0.03571	0.029787	0.0000	0.0949	0.02645
p	0.03070	0.033631	0.0000	0.1535	0.01980
w	0.01668	0.022483	-0.0261	0.0701	0.01295

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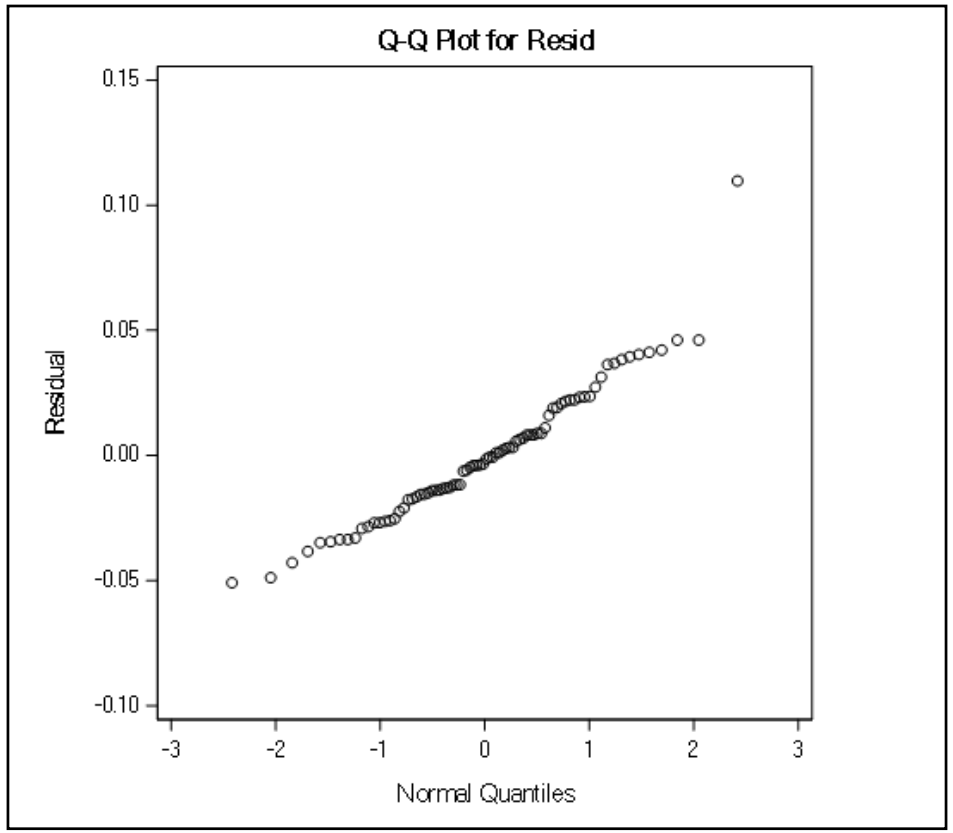
Weight Data

Weight change was regressed against number of cycles and type of fabric.



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Weight Data

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
cycles	2	73	14.19	<.0001
Fabric	3	73	21.51	<.0001

Least Squares Means										
Effect	Fabric	cycles	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
cycles		0	-694E-20	0.008387	73	-0.00	1.0000	0.05	-0.01671	0.01671
cycles		1	0.03448	0.003954	73	8.72	<.0001	0.05	0.02660	0.04236
cycles		2	0.04871	0.004012	73	12.14	<.0001	0.05	0.04072	0.05671
Fabric	m		0.02600	0.005692	73	4.57	<.0001	0.05	0.01466	0.03735
Fabric	p		0.01512	0.005806	73	2.61	0.0111	0.05	0.003554	0.02670
Fabric	w		0.006975	0.005692	73	1.23	0.2244	0.05	-0.00437	0.01832
Fabric	c		0.06281	0.005692	73	11.04	<.0001	0.05	0.05147	0.07416

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Weight Data

Differences of Least Squares Means										
Effect	Fabric	cycles	Fabric	cycles	Estimate	Standard Error	t Value	Pr > |t|	Lower	Upper
cycles		0		1	-0.03448	0.009272	-3.72	0.0004	-0.05296	-0.01600
cycles		0		2	-0.04871	0.009297	-5.24	<.0001	-0.06724	-0.03018
cycles		1		2	-0.01423	0.005633	-2.53	0.0137	-0.02546	-0.00301
Fabric	m		p		0.01088	0.007601	1.43	0.1566	-0.00427	0.02603
Fabric	m		w		0.01903	0.007501	2.54	0.0133	0.004080	0.03398
Fabric	m		c		-0.03681	0.007501	-4.91	<.0001	-0.05176	-0.02186
Fabric	p		w		0.008150	0.007601	1.07	0.2871	-0.00700	0.02330
Fabric	p		c		-0.04769	0.007601	-6.27	<.0001	-0.06284	-0.03254
Fabric	w		c		-0.05584	0.007501	-7.44	<.0001	-0.07079	-0.04089

Crew Clothing Care

Conclusion

- Smell data:
  - Wool was the fabric most likely to have no smell.
  - Two cycles are needed to make an impact.
- Stain data:
  - Cotton was the fabric to most likely have no stain.
  - Only one cycle is need to make an impact.
- Weight change data:
  - Cotton had the greatest weight change.
  - The greater the cycles the more weight loss will occur.
- Modacrylic was the least likely to get clean by smell or sight.

Men in Black

Background

- This study is trying to determine if people prefer cotton to wool for everyday wear for a reason or because of a preconceived idea that it's itchy or scratchy.
- Merino wool is a very specific type of wool known for its breathability and in this study virtually undisguisable from cotton.
- Wool is lighter and more flame retardant than cotton.

Men in Black

Set-up

- Twelve participants wore different t-shirts as undershirts to work, without washing them, until they didn't want to anymore.
- At the end of everyday the participant filled out a questionnaire. Recording their answers on a visual analog scale.
- When they we're no longer happy with the t-shirt they had they turned it in and received a different t-shirt.
- There were four brands of t-shirts, three merino wool and one cotton.

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Men in Black

1. How soft do you perceive this shirt to be? _____
2. How satisfied are you with your upper body odor? _____
3. How dry is this shirt through the day? _____
4. How do you feel this shirt keeps perspiration from your skin? _____
5. How confident do you feel wearing this shirt in public? _____
6. How satisfied are you with this shirt's ability to keep you thermally comfortable? _____
7. How comfortable is this shirt overall? _____

Men in Black

Design

- This is a cross-over design with a washout period.
- This was a single blind study.
- Shirt types:
  - A- Armadillo Merino
  - B- Icebreaker
  - C- Kit Clothiers
  - D- Cotton

Participant	Period		
	1	2	3
1	A	B	C
2	B	A	D
3	C	D	A
4	D	C	B
5	A	D	B
6	B	C	A
7	C	B	D
8	D	A	C
9	A	C	D
10	B	D	C
11	C	A	B
12	D	B	A

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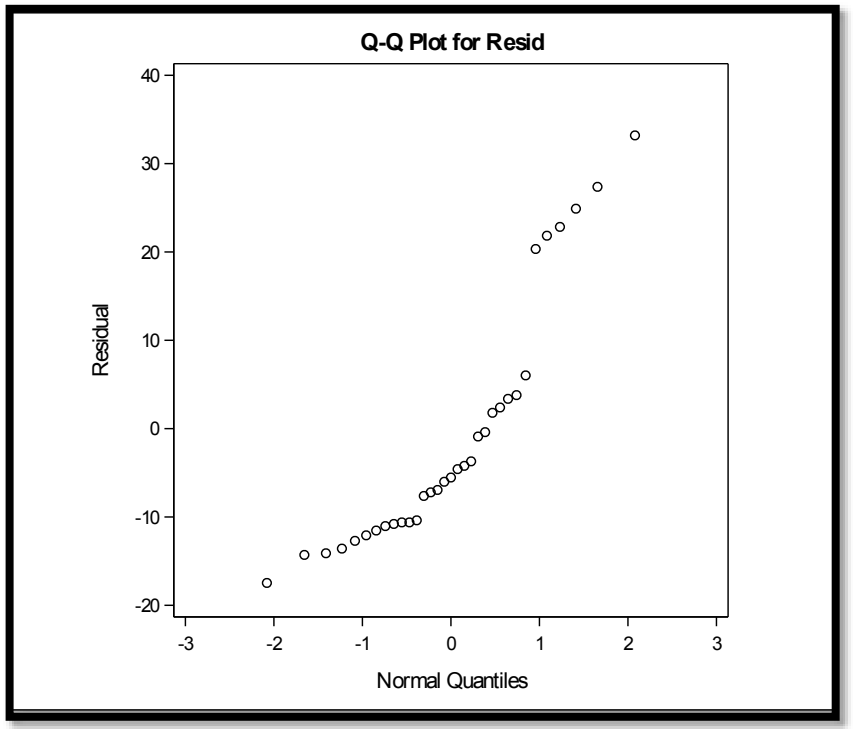
Length of Wear Data

Fabric	Total Number of Shirts	Minimum Days	Maximum Days	Range of Days	Mean Days	Median Days
Armadillo Merino	7	7	66	59	19.5714	10
Icebreaker	9	6	61	55	25.4444	25
Kit Clothiers	8	6	65	59	25.8750	12
Cotton	9	5	62	57	26.2222	16

Men in Black

Length of Wear Analysis

- Length of wear data was regressed against the types of fabric.
  - Participants were modeled as a random effect.
  - The periods were modeled as a repeated measure.
- The residuals were not independent and identically normally distributed.



Tests for Normality				
Test	Statistic		p Value	
Kolmogorov-Smirnov	D	0.187474	Pr > D	<0.0100

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Length of Wear Analysis – Box-Cox Transformation

$$\tilde{y}_i = \frac{(y_i)^{\hat{\lambda}} - 1}{\hat{\lambda} \times (\hat{y})^{\hat{\lambda}-1}}$$

When the best lambda is zero the equation becomes:

$$\tilde{y}_i = \hat{y} \log_e y_i$$

Lambda		R-Square	Log Like	
-1.00		0.83	-74.5726	
-0.75		0.85	-70.8721	
-0.50		0.85	-68.4793	*
-0.25		0.86	-67.5850	<
0.00	+	0.85	-68.2491	*
0.25		0.84	-70.3775	
0.50		0.83	-73.7685	
0.75		0.82	-78.1867	
1.00		0.81	-83.4183	

< - Best Lambda
*** - 95% Confidence Interval**
+ - Convenient Lambda

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Length of Wear Analysis

- The model was run again using data transformed by taking the natural log instead of using the Box Cox transformation.
- This data still approximately follows the log normal distribution since multiplying my the geometric mean is a linear transformation.

Fit Statistics (Box Cox)	
-2 Log Likelihood	250.0
AIC (Smaller is Better)	264.0
AICC (Smaller is Better)	268.5
BIC (Smaller is Better)	267.4

Fit Statistics (Natural Log)	
-2 Log Likelihood	60.3
AIC (Smaller is Better)	74.3
AICC (Smaller is Better)	78.8
BIC (Smaller is Better)	77.7

Men in Black

Length of Wear Analysis

- The natural log transformed length of wear data was regressed against the types of fabric.
  - Participants were modeled as a random effect.
  - The periods were modeled as a repeated measure.
- The type 3 tests are answering if the means of the transformed length of wear data are equal for every type of fabric.

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Fabric	3	18	0.84	0.4901

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Length of Wear Analysis

Differences of Least Squares Means								
Fabric	minus Fabric	Estimated Difference	Standard Error	DF	t Value	Pr > |t|	95% Confidence Limit	
Armadillo Merino	Cotton	-4.6573	3.6442	18	-1.28	0.2175	-12.3134	2.9989
Armadillo Merino	Icebreaker	-5.0824	3.5414	18	-1.44	0.1684	-12.5227	2.3578
Armadillo Merino	Kit Clothiers	-4.4024	3.7260	18	-1.18	0.2528	-12.2303	3.4256
Cotton	Icebreaker	-0.4251	3.4338	18	-0.12	0.9028	-7.6393	6.7890
Cotton	Kit Clothiers	0.2549	3.4907	18	0.07	0.9426	-7.0788	7.5887
Icebreaker	Kit Clothiers	0.6801	3.6099	18	0.19	0.8527	-6.9041	8.2643

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Length of Wear Analysis

This table gives the least squares means and 95% confidence limits on those means after back transforming the data.

Fabric	Estimated Days Worn	95% Confidence Limit on LS Means	
Armadillo Merino	15.2133	8.7466	26.4610
Cotton	19.7865	11.6765	33.5292
Icebreaker	20.2670	11.9569	34.3527
Kit Clothiers	19.5037	11.3708	33.4537

Men in Black

Length of Wear Analysis

- The next model ran regressed the natural log of days worn against the type of fabric, the participant and the period.
- This model gave the same conclusion about fabric type.

Type III Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
Participant	11	184.2713	<.0001
Period	2	4.3179	0.1154
Fabric	3	4.8438	0.1836

Men in Black

Preference Data

- The lengths of the lines on the visual analog scale changed when copied or printed so all responses had to be rescaled and now range between zero to one.

- The responses per page seem to be highly correlated.

Men in Black

Preference Data

	Means of Scaled Responses							
	Question							
	1	2	3	4	5	6	7	All
Fabric								
Armadillo Merino	0.85	0.85	0.89	0.89	0.84	0.88	0.84	0.86
Icebreaker	0.86	0.87	0.90	0.90	0.87	0.88	0.86	0.88
Kit Clothiers	0.83	0.74	0.83	0.82	0.75	0.80	0.80	0.80
Cotton	0.88	0.83	0.85	0.84	0.83	0.86	0.85	0.85
All	0.86	0.82	0.87	0.86	0.82	0.85	0.84	0.85

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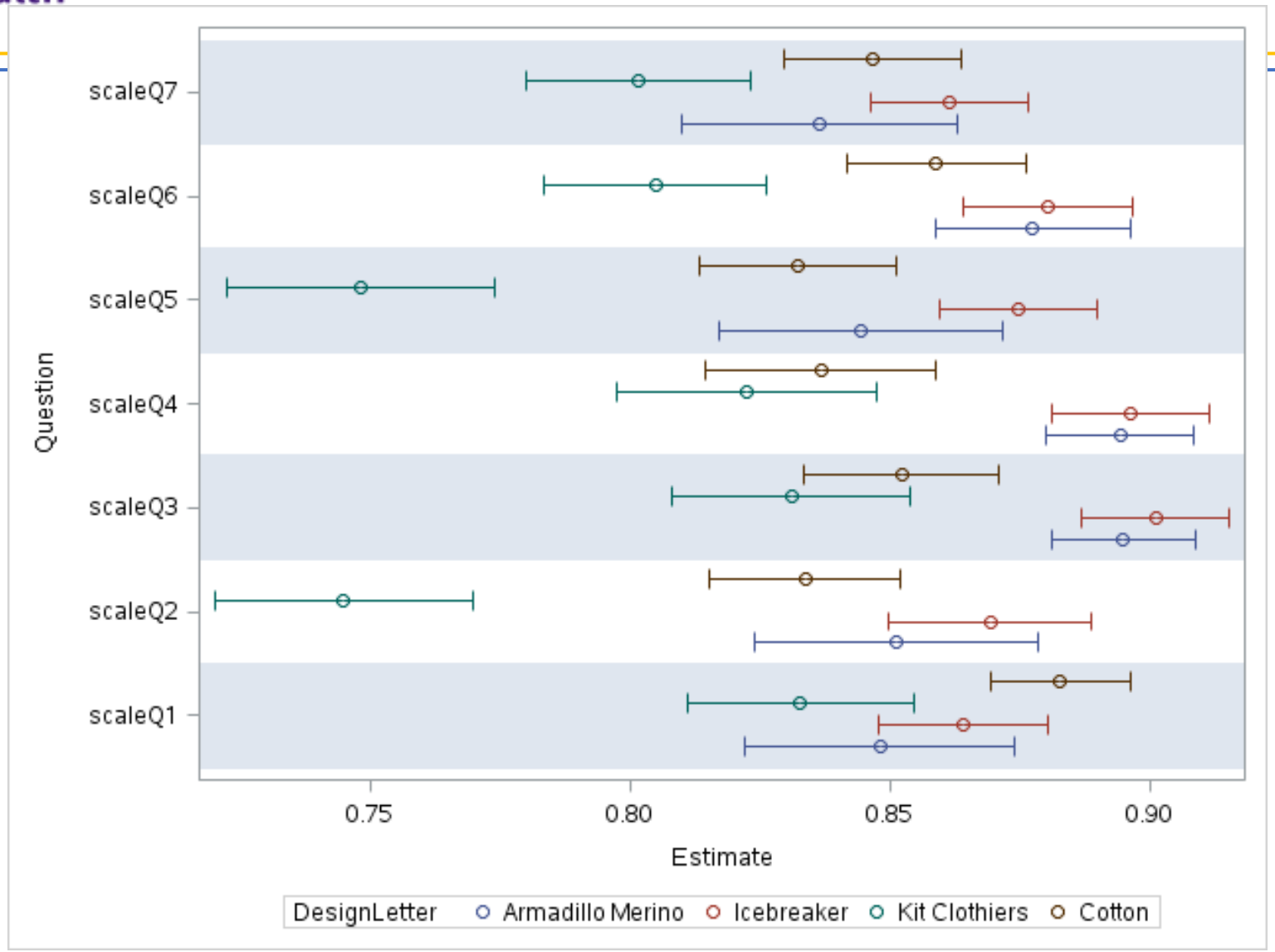

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Men in Black

NASA

Conclusion and Future Steps

- From the length of wear data it is clear that cotton was not worn for any more or less time than Merino wool.

- Preference data needs to be analyzed.

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Internship Experience

- There is no one-size-fits-all solution to a problem.
- I improved my coding skills.
- I saw the practical applications of my school studies.

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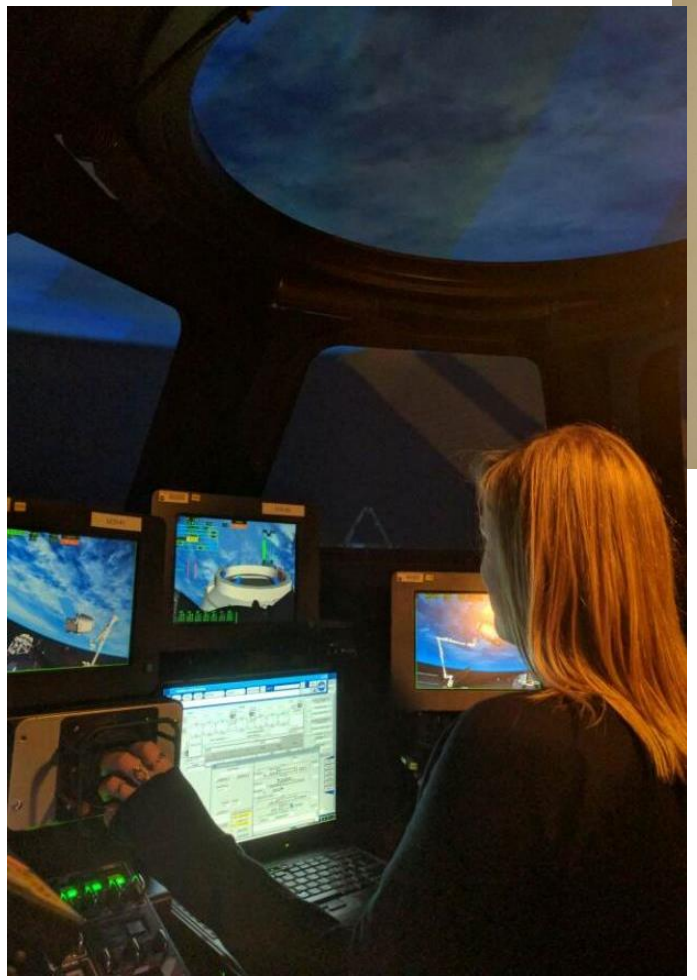
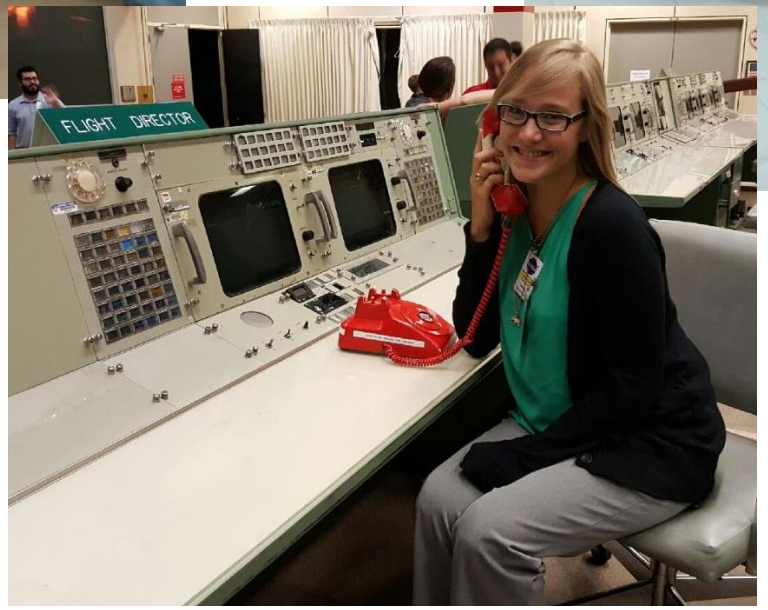
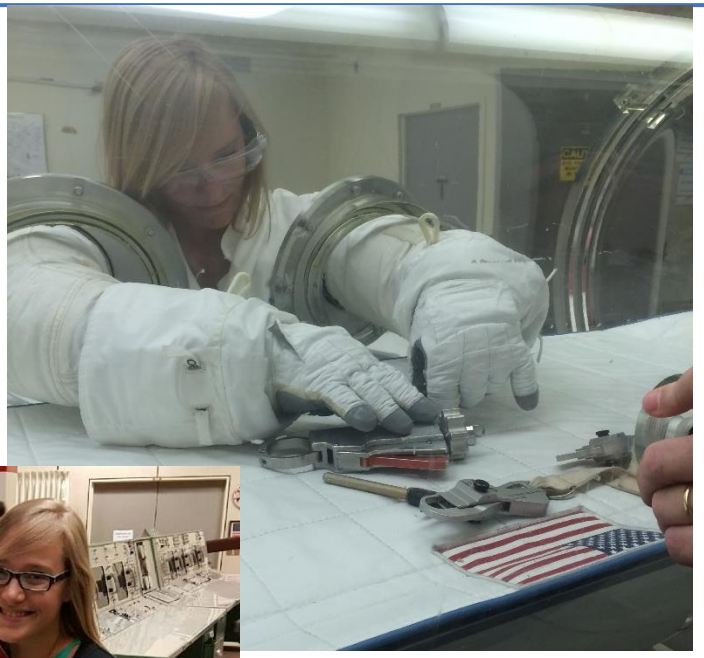
Internship Experience







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Thank you!

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