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External Tank Liquid Hydrogen (LH2) Prepress Regression Analysis Independent Review Technical Consultation Report

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May 2009

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Space Administration

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1.0 Authorization and Notification

The request to conduct an independent review of regression models, developed for determining the expected Launch Commit Criteria (LCC) External Tank (ET)-04 cycle count for the Space Shuttle ET tanking process, was submitted to the NESC on September 20, 2005.

NESC acceptance of this task was approved in an out-of-board action on October 7, 2005.

2.0 Signature Page

Consultation Team Members

Vickie S. Parsons, NESC Lead	K. Preston White, University of Virginia

3.0 Team Members, Ex Officio Members, and Consultants

Vickie Parsons	NESC Systems Engineer	NASA LaRC
K. Preston White	Statistical Consultant	University of Virginia
Bernie Mylnczak	NESC Program Analyst	MTSO, LaRC
Erin Moran	Technical Writer	Swales Aerospace, LaRC

4.0 Executive Summary

The NESC team performed an independent review of regression models documented in *Prepress Regression Analysis*, Tom Clark and Angela Krenn, 10/27/05. These regressions were developed for determining the expected cycle count described in LCC ET-04. This independent review was limited to regression models developed based on variable measurements that are available prior to launch and corresponding to the development of "regression #1", pp 4-7, in *Prepress Regression Analysis*.

5.0 Consultation Plan

This consultation consisted of a peer review by statistical experts of the proposed regression models provided in the *Prepress Regression Analysis*. Both primary members of the NESC team reviewed the following documents:

- Prepress Regression Analysis, Tom Clark & Angela Krenn (10/27/05)
- STS-114 S0007#2 LCC ET-04 LH_2 Prepress Cycle Count, Diane Stees (7/29/05)
- STS-114 S0037#2 LH_2 Prepress Test Cycle Count, Diane Stees (5/26/05)
- Define Mechanization of GH_2 Prepress Cycle Count LCC ET-04, Diane Stees (2/12/03)
- Launch Commit Criteria (LCC) ET-04
- Launch Commit Criteria (LCC) ET-05
- LH_2 Tank Prepress Overview (LCCs ET-04 & ET-05), B. Piekarski (10/27/05)
- Flight Pressurization System ET-04 Assessment LH_2 Vent Vale Hazard Review, Kathryn Kynard & Jonathan Looser (10/24/05)
- Transient Analysis of LH_2 Tank Prepress Helium Mass Flow, Adam Baran (10/27/05)
- Lockheed Martin Pressurization Program, B. Piekarski (10/27/05)
- Flight Pressurization System ET-04 Assessment ER21 Pressurization Model Sensitivity ER21, Tim Olive (10/24/05)

A telephone conference was also conducted between the NESC team and Space Shuttle Program (SSP) members knowledgeable of the ET tanking process, LCC ET-04, LCC ET-05, and the cycle count process.

6.0 Description of the Problem, Proposed Solutions, and Risk Assessment

The SSP uses LCC ET-04 as an indirect method to monitor ET LH_2 vent valve leakage. LCC ET-04 monitors the LH_2 tank pre-press system by counting GHe press valve command cycles. A larger than predicted command-cycle count is an indicator of potentially dangerous leakage and can lead to aborting the launch. The most recent valve replacements appear to have faster cycle times than those for the valves previously employed. Because the shorter pulse time leads to a lower helium make-up input per command cycle, a higher cycle count is required to maintain the ET pressure. The STS-114 ET tank loading observed 11 cycles which constituted 2 greater than predicted for the prior valves. This highlighted the need for revised modeling to better predict expected cycles with the current valves.

The SSP's intent is to use modeling that is currently under development to determine appropriate modifications to the applicable LCCs. The intended application of these regressions is to provide a simple tool to validate the NASA-accredited, analytical (first principles) model currently under development, against empirical data available since the transition to half-second valve pulses. Additional analyses have been performed to verify that ground valve cycle timing does approximate the average cycle count.

7.0 Data Analysis

The data set for the review is provided in Table 7.0-1. The set comprises a total of twenty-seven data records, including records for seventeen flights (STS-88, -92, -93, -95, and -114), as well as one tanking test for STS-91 and three tanking tests for STS-114.

The dependent (output) variable in each data record is:

ActLCC: Actual (integer) number of cycles experienced plus the amount of time (as a fraction) between last and subsequent cycle at which point the LCC expires (T-43s). This combination variable was chosen by the SSP team rather than the integer number of cycles because a continuous variable is better suited to regression analyses.

The independent (predictor) variables are:

Mission: Mission identifying number.

Orbiter: Orbiter number.

MLP: Mobile launch pad number.

Diffuser: Indicator variable for the diffuser material (0 indicating Single Dutch Twill and 1 indicating Double Dutch Twill).

UllagePres: The trigger point software to control the tank at flight pressure (pulse fired when 2 of 3 ullage pressure transducers fall below the trigger point).

SupplyPres: The GHe pressure coming into the panel and remains fairly constant throughout launch operations.

SFOutPres: Peak (steady state) panel outlet pressure during initial pressurization in Slow Fill (to 5 percent full).

TCOutPres: Peak panel outlet pressure during initial pressurization in Terminal Count.

CycleTime: Average prepress s/o valve cycle time in Terminal Count (LCC prepress cycles only). Similar data can be obtained prior to loading to predict an LCC cycle count.

PeakPress: Average peak panel outlet pressure during Terminal Count (LCC prepress cycles only).

Temp: Ambient outside temperature during Slow Fill (to 5 percent full).

Prepres: Peak Orbiter prepress line pressure during initial pressurization in Slow Fill (to 5 percent full).

Other variables that were provided in the data set were discounted because they were not known early enough in the tanking process. For analysis, the three category variables *Orbiter, MLP*, and *Diffuser* were translated to 0-1 indicator (dummy) variables.

Table 7.0-1. Data Set for the Review

Mission	ActLCC	Orbiter	MLP	Diffuser	UllagePres	SupplyPres	SFOutPres	TCOutPres	CycleTime	PeakPres	Temp	PrePres
88	7.79	5	3	0	41.8	1960	1064	1072	0.515	808.0	74.0	208
92	9.13	3	3	0	41.8	1980	1080	1088	0.518	828.0	73.6	232
93	8.54	2	1	0	41.8	2000	1048	1032	0.499	816.0	86.0	200
95	8.55	3	2	0	41.8	2040	1024	1016	0.518	824.0	61.2	220
96	10.11	3	2	0	41.8	2040	1000	1000	0.496	760.0	75.6	216
97	7.70	5	1	0	41.8	2020	1088	1080	0.505	802.3	67.6	216
98	11.12	4	2	0	41.8	2060	1016	1016	0.469	720.7	60.4	196
99	7.05	5	3	0	41.8	1980	1080	1088	0.512	827.4	48.8	212
100	9.09	5	1	0	41.8	2000	1056	1048	0.504	794.7	51.6	208
101	8.16	4	1	0	41.8	1980	1080	1064	0.514	813.0	75.2	212
102	8.10	3	3	0	41.8	1940	1048	1048	0.503	791.0	48.4	228
103	10.44	3	2	0	41.8	2080	1024	1016	0.466	731.2	66.4	220
104	10.07	4	2	0	41.8	2020	1016	1016	0.489	747.2	77.6	192
105	8.50	3	3	0	41.8	1980	1104	1104	0.524	858.0	78.0	236
106	10.51	4	2	0	41.8	2060	1016	1016	0.502	762.4	79.6	196
107	10.26	2	1	0	47.0	1980	1048	1040	0.511	761.6	47.2	200
108	8.02	5	1	0	41.8	2060	1080	1072	0.515	802.0	72.8	212
109	9.11	2	2	0	41.8	2040	1016	1016	0.468	722.7	52.8	188
110	9.05	4	3	0	47.0	1960	1112	1112	0.522	853.3	69.6	216
111	9.44	5	1	0	47.0	2020	1064	1056	0.518	814.2	81.2	212
112	9.19	4	3	0	47.0	1920	1104	1104	0.526	858.7	72.8	216
113	11.08	5	2	0	47.0	2060	1056	1056	0.487	800.0	55.2	204
114	11.81	3	3	0	46.5	1960	1080	1080	0.449	718.6	78.0	232
114T1	13.52	3	1	1	46.5	2080	1080	1080	0.505	799.4	59.2	236
114T2	13.65	3	1	1	46.5	2040	1064	1056	0.509	792.6	68.8	232
114T2	14.15	3	1	1	46.5	2040		1056	0.531	809.7		
91T	9.25	3	1	0	46.7	2040	1048	1040	0.492	808.0	71.6	232

All three tanking tests for STS-114 yielded large cycle counts resulting from a known anomaly caused by use of an out-of-specification material (Double Dutch Twill) for diffusers. This anomaly is illustrated in the box plot in Figure 7.0-1. Appendix B provides a key for interpreting box plots.

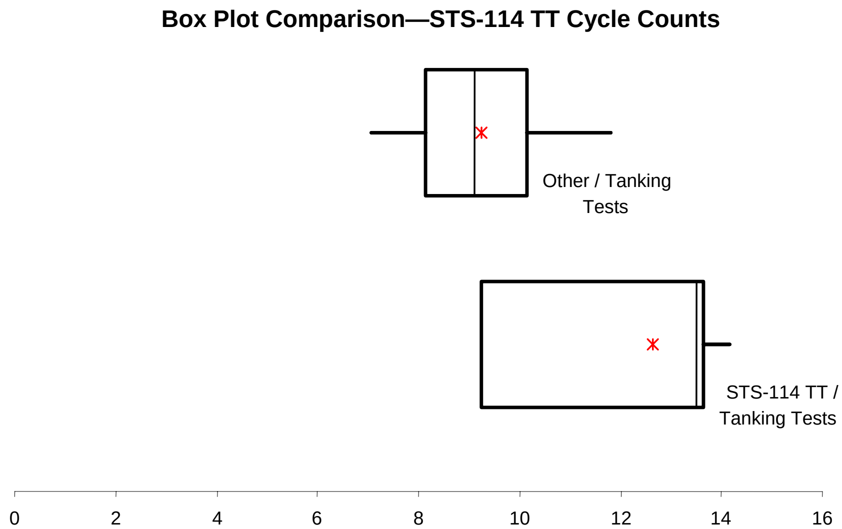

Figure 7.0-1. Comparison of Elevated Cycle Counts Resulting from Incorrect Diffuser Material on Three STS-114 Tanking Tests with Cycle Counts for the Remaining Data Records

Additionally, the set of eight launches using MLP-2 (STS-95, -96, -98, -103, -104, -106, -109, and -113) have larger cycle counts, resulting from a known anomaly caused by a restrictive upstream orifice. This anomaly is illustrated in the box plot in Figure 7.0-2 (where the anomalous STS-114 tanking tests have been removed from the data set).

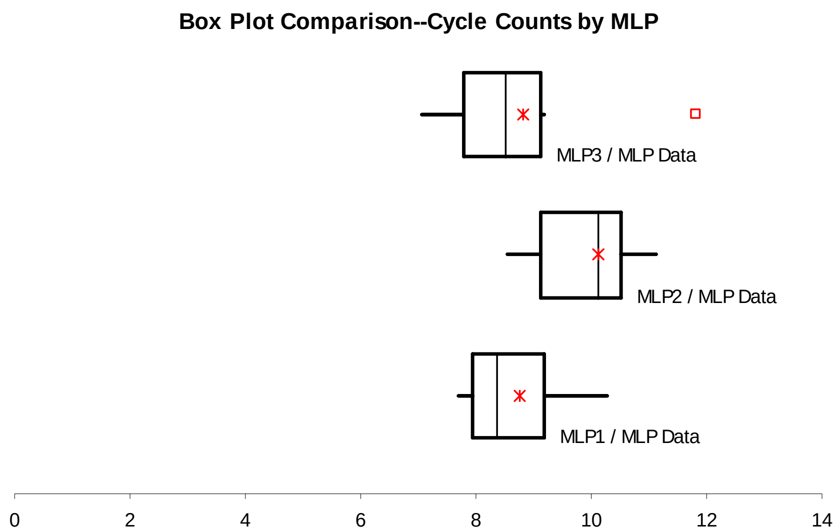

Figure 7.0-2. Comparison of Elevated Cycle Counts Resulting from Undersized Orifice on MLP-2 with Cycle Counts for the Remaining Data Records

The causes of these anomalous cases have been corrected and are unlikely to be repeated.

Meaningful regressions require that the independent variables be unrelated. To assess potential co-linearities in the predictor variables, cross-correlation coefficients were computed for each pair of predictor variables, as shown in Table 7.0-2. When both variables were interval level measurements, Pearson's correlation coefficient was used; when either variable was categorical, Spearman's correlation coefficient was used.

Those values that were significant at .05 or better are shown in bold, indicating that those pairs of variables would not be good candidates within the same regression.

Table 7.0-2. Correlation Coefficients for the Potential Independent Predictor Variables

	Mission	Diffuser	UllagePres	MLP	SupplyPres	SFOutPres	TCOutPres	CycleTime	PeakPress	Temp.
Mission										
Diffuser	**0.545**									
UllagePres	**0.606**	0.290								
MLP	-0.118	**-0.387**	-0.139							
SupplyPres	0.142	0.324	-0.063	**-0.500**						
SFOutPres	0.271	0.146	0.368	0.178	**-0.539**					
TCOutPres	0.248	0.122	0.337	0.301	**-0.560**	**0.980**				
CycleTime	0.097	0.204	0.110	0.060	-0.313	**0.516**	**0.478**			
PeakPres	-0.146	-0.030	0.172	0.147	**-0.418**	**0.704**	**0.679**	**0.852**		
Temp	-0.071	-0.154	-0.029	0.035	-0.033	0.116	0.077	0.098	0.159	
PrePres	0.085	**0.407**	0.273	0.163	-0.157	**0.501**	**0.497**	0.208	**0.387**	0.107

A stepwise linear regression was performed using all of the data records except STS-114 tanking test 2 (where data values were missing for three predictors). The results using *p*-values to determine the significance levels of the variable entering are shown in Table 7.0-3. The results using *F*-ratio values to determine the significance levels of the variable entering is shown in Table 7.0-4. The results are clearly very similar, with *Diffuser, UllagePres, MLP=2* all significant predictors in both cases. In the first regression, *CycleTime* also is significant; in the second regression, *PeakPres* replaces *CycleTime* (in the final step) and *Temp* is also significant.

- *Diffuser* variable dominates the regression. In essence, diffuser is an indicator for the known anomalies on the STS-114 tanking tests included in the data.
- Similarly, *MLP=2* is an indicator for the known anomalies caused by an undersized upstream orifice.

In other words, the regression flags the anomalies, as it should.

- *PeakPres* and *CycleTime* are known to be highly correlated and one or the other (but not both) will be included, if the associated data indicate significance, as these do.
- *Temp* is included in the second regression and not the first, but is an order of magnitude less significant than any of the other included predictors.

These results confirm that Clark and Krenn have included the appropriate, and only the most appropriate, predictors in their regression.

Table 7.0-3. Stepwise Regression on all Data using P-Value to Determine Significance of Entering Variables

Summary	**Multiple R**	**R-Square**	**Adjusted R-Square**	**StErr of Estimate**	**Durbin Watson**	
	0.9285	0.8620	0.8358	0.671216686	2.2440	
ANOVA Table	**Degrees of Freedom**	**Sum of Squares**	**Mean of Squares**	**F-Ratio**	**p-Value**	
Explained	4	59.12244675	14.78061169	32.8070	< 0.0001	
Unexplained	21	9.461168632	0.45053184			
Regression Table	**Coefficient**	**Standard Error**	**t-Value**	**p-Value**	**Lower Limit**	**Upper Limit**
Constant	10.73676745	5.096139221	2.1068	0.0473	0.138765773	21.33476913
Diffuser	3.999890394	0.532004437	7.5185	< 0.0001	2.8935266	5.106254187
CycleTime	-26.5983152	7.861564618	-3.3833	0.0028	-42.9473338	-10.2492966
UllagePres	0.265240602	0.061726836	4.2970	0.0003	0.136872618	0.393608586
MLP = 2	1.077573737	0.347955906	3.0969	0.0055	0.353959817	1.801187657
Step Information	**Multiple R**	**R-Square**	**Adjusted R-Square**	**StErr of Estimate**	**Enter or Exit**	
Diffuser	0.7108	0.5052	0.4846	1.189133891	Enter	
CycleTime	0.8458	0.7154	0.6906	0.921254182	Enter	
UllagePres	0.8939	0.7990	0.7716	0.791489885	Enter	
MLP = 2	0.9285	0.8620	0.8358	0.671216686	Enter	

Table 7.0- 4. Stepwise Regression on all Data using *F*-ratio Values to Determine Significance of Entering Variables

Summary	Multiple R	R-Square	Adjusted R-Square	StErr of Estimate	Durbin Watson	
	0.9367	0.8774	0.8467	0.648478308	2.2195	
ANOVA Table	Degrees of Freedom	Sum of Squares	Mean of Squares	F-Ratio	p-Value	
Explained	5	61.44086087	12.28817217	34.4074	< 0.0001	
Unexplained	20	7.142754517	0.357137726			
Regression Table	Coefficient	Standard Error	t-Value	p-Value	Lower Limit	Upper Limit
Constant	6.847746674	3.728120462	1.8368	0.0812	-0.928976336	14.62446968
Diffuser	3.817194075	0.477827428	7.9886	< 0.0001	2.820463526	4.813924625
UllagePres	0.298677801	0.05454566	5.4757	< 0.0001	0.184897548	0.412458053
MLP = 2	0.93811152	0.322786866	2.9063	0.0087	0.264789916	1.611433125
Temp	0.021727083	0.010771308	2.0171	0.0573	-0.00074147	0.044195638
PeakPres	-0.01552637	0.003583316	-4.3330	0.0003	-0.02300103	-0.00805170
Step Information	Multiple R	R-Square	Adjusted R-Square	StErr of Estimate	Enter or Exit	
Diffuser	0.7108	0.5052	0.4846	1.189133891	Enter	
CycleTime	0.8458	0.7154	0.6906	0.921254182	Enter	
UllagePres	0.8939	0.7990	0.7716	0.791489885	Enter	
MLP = 2	0.9285	0.8620	0.8358	0.671216686	Enter	
Temp	0.9367	0.8774	0.8467	0.648478308	Enter	
PeakPres	0.9473	0.8974	0.8650	0.608639466	Enter	
CycleTime	0.9465	0.8959	0.8698	0.597610012	Exit	

The scatterplot of the fit versus the actual cycle count output in Figure 7.0-3 confirms that the residuals appear to be random and that the linear model correctly captures the relationships in the data.

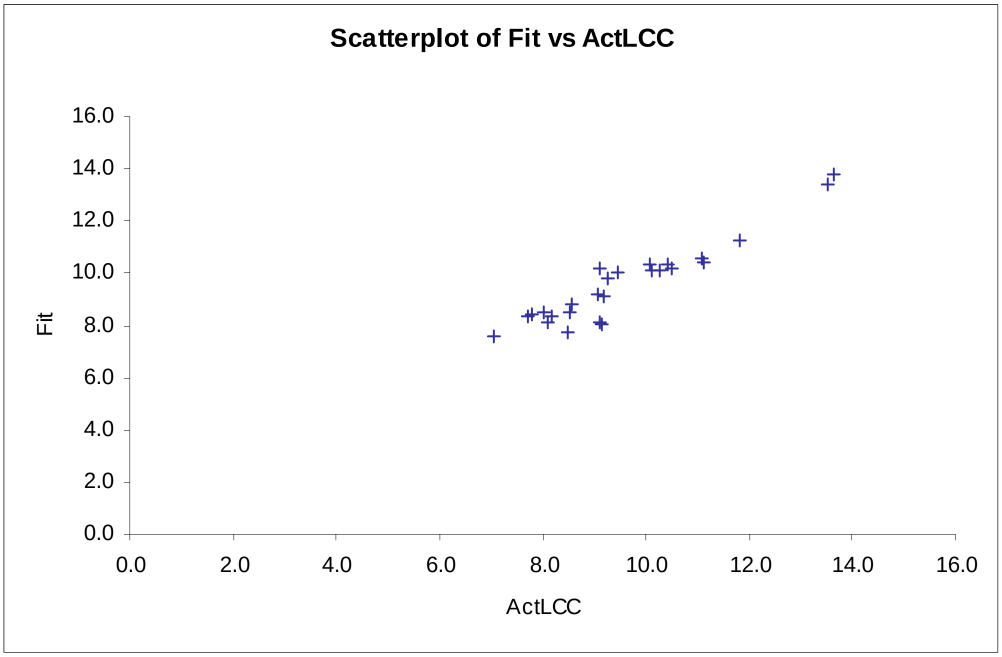

Figure 7.0-3. Scatterplot of the fit versus actual cycle count for the regression on all variables

Next, *CycleTime*, *MLP-2*, and *Orbiter* variables were eliminated from the data set to be consistent with the data employed by Clark and Krenn in *Prepress Regression Analysis*, which also restored the record for STS-114 tanking data omitted from the previous regression.

Stepwise regression was applied to the resulting data set. The results agree exactly with the two-variable “regression #1” reported by Clark and Krenn, as shown in Table 7.0-5.

Table 7.0-5. Stepwise Regression Corresponding to Clark and Krenn

Summary	Multiple R	R-Square	Adjusted R-Square	StErr of Estimate	Durbin Watson	
	0.9297	0.8643	0.8466	0.723270396	2.1341	
ANOVA Table	**Degrees of Freedom**	**Sum of Squares**	**Mean of Squares**	**F-Ratio**	**p-Value**	
Explained	3	76.60911257	25.53637086	48.8155	< 0.0001	
Unexplained	23	12.0317615	0.523120065			
Regression Table	**Coefficient**	**Standard Error**	**t-Value**	**p-Value**	**Lower Limit**	**Upper Limit**
Constant	13.78872186	3.642964275	3.7850	0.0010	6.252676093	21.32476764
Diffuser	3.831753215	0.488181847	7.8490	< 0.0001	2.821872122	4.841634309
PeakPres	-0.02012713	0.003559934	-5.6538	< 0.0001	-0.02749142	-0.01276285
UllagePres	0.263784397	0.064649407	4.0802	0.0005	0.130046909	0.397521885
Step Information	**Multiple R**	**R-Square**	**Adjusted R-Square**	**StErr of Estimate**	**Enter or Exit**	
Diffuser	0.7841	0.6147	0.5993	1.168755963	Enter	
PeakPres	0.8752	0.7660	0.7465	0.929623706	Enter	

The regression was repeated with the same data *scaled* from 0 to 1. The scaled value of any variable x_i is $z_i=(x_i-x_imin)/(x_imax-x_imin)$. The regression statistics shown in Table 7.0-6 are the same (as these must be) as before, but the scaling makes the regression coefficients easier to interpret — the coefficients are now proportional to the significance of the corresponding variables in the regression.

Table 7.0-6. Stepwise Regression Corresponding to Clark and Krenn using Scaled Values

Summary	Multiple R	R-Square	Adjusted R-Square	StErr of Estimate	Durbin Watson	
	0.9297	0.8643	0.8466	0.10186907	2.1341	
ANOVA Table	**Degrees of Freedom**	**Sum of Squares**	**Mean of Squares**	**F-Ratio**	**p-Value**	
Explained	3	1.519720543	0.506573514	48.8155	< 0.0001	
Unexplained	23	0.23867807	0.010377307			
Regression Table	**Coefficient**	**Standard Error**	**t-Value**	**p-Value**	**Lower Limit**	**Upper Limit**
Constant	0.465006748	0.042789934	10.8672	< 0.0001	0.376489024	0.553524471
Scaled Diffuser	0.539683551	0.068758007	7.8490	< 0.0001	0.397446778	0.681920325
Scaled PeakPress	-0.39715663	0.07024602	-5.6538	< 0.0001	-0.542471598	-0.25184167
Scaled Ullage	0.193194206	0.047348862	4.0802	0.0005	0.095245623	0.291142789
Step Information	**Multiple R**	**R-Square**	**Adjusted R-Square**	**StErr of Estimate**	**Enter or Exit**	
Scaled Diffuser	0.7841	0.6147	0.5993	0.164613516	Enter	
Scaled PeakPress	0.8752	0.7660	0.7465	0.130932916	Enter	

The three-variable regression yields an adjusted R^2 of .8466. However, the regression again is dominated by the *Diffuser* variable, which alone explains about 61.47 percent of the variation.

The scatterplot of the fit versus the actual cycle count output shown in Figure 7.0-4 confirms that the residuals appear to be random and that the linear model correctly captures the relationships in the data.

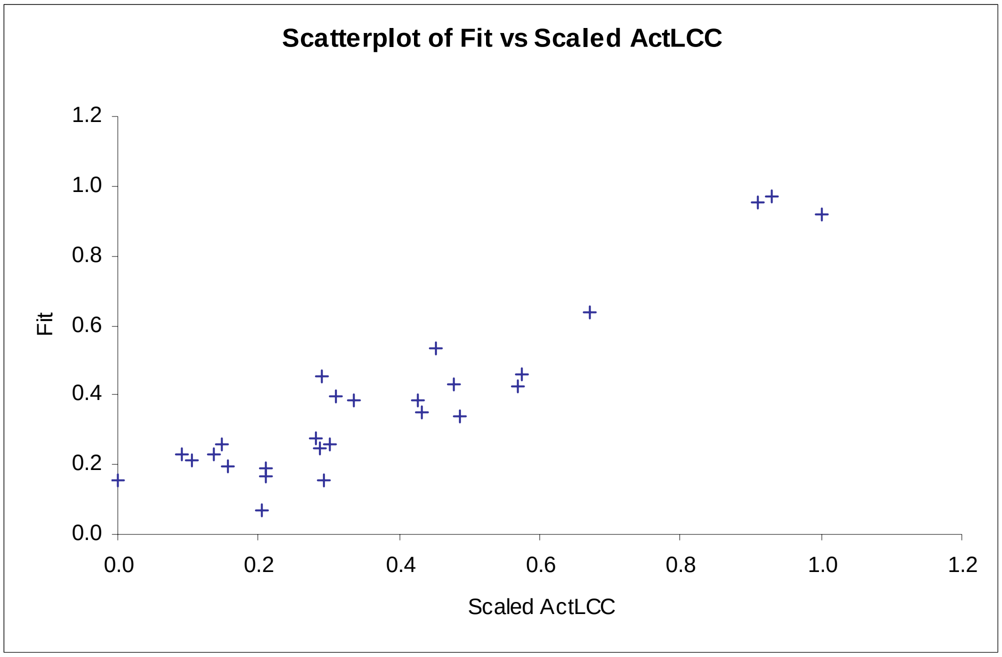

Figure 7.0-4. Scatterplot of the Fit Versus Scaled Actual Cycle Count for the Regression on all Variables

Scaling the data also permits box plots for all of the variables and variable interactions in the regression on the same scale, as shown in Figure 7.0-5. The data anomalies previously described are clearly reflected in the outliers in these plots.

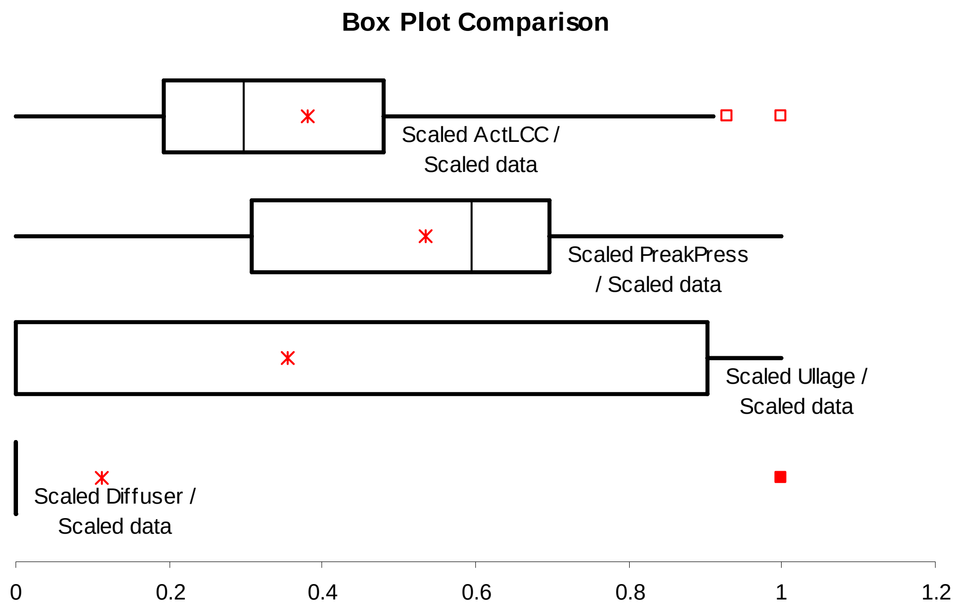

Figure 7.0-5. Comparison of Scaled Output and Predictor Variables for the Clark and Kreen Comparison

Scatterplots of the output versus each of the three predictor variables included are shown in Appendix B.

It should be noted that examining the residuals (the differences between the observed and predicted output at each data point) for randomness is important in any regression analysis. A pattern in the residuals indicates that the underling relationship is nonlinear and that superior regression can be achieved by a suitable transformation of the data. In all of the regressions developed in this review, examination of the residuals confirmed the apparent linearity of the relationship modeled.

Regression #1, developed by Clark and Krenn, is based on three independent (predictor) variables which can be measured well prior to launch. However, the data set used to develop this regression includes data that is no longer representative of the tanking operations that should occur in the future. Primarily, the diffuser variable dominates the regression and the out-of-specification material problem with the diffusers in the STS-114 tanking tests has been resolved. All diffuser material will be single twill in the future. In addition, the MLP-2 restriction problem upstream of the panel has been fixed and MLP-2 cycles should be within the realm of the other MLPs in the future. Since the data on which this regression was based are not homogenous, replacing variables (Diffuser & UllagePress) with values that have now become standard is not statistically acceptable.

Therefore, an additional stepwise linear regression was performed excluding the data points where the Double Dutch Twill Diffuser was used (STS 114 tanking tests) and where MLP was equal to 2. The results of this regression are shown in Table 7.0-7.

Table 7.0-7. Stepwise Regression Based on Subset of Data that is Relevant to Current and Future Conditions

Summary	**Multiple R**	**R-Square**	**Adjusted R-Square**	**StErr of Estimate**		
	0.8419	0.7088	0.6640	0.655232234		
ANOVA Table	**Degrees of Freedom**	**Sum of Squares**	**Mean of Squares**	**F-Ratio**	**p-Value**	
Explained	2	13.58341936	6.791709681	15.8193	0.0003	
Unexplained	13	5.581280638	0.42932928			
Regression Table	**Coefficient**	**Standard Error**	**t-Value**	**p-Value**	**Confidence Interval 95% Lower**	**Upper**
Constant	11.76671334	6.039583426	1.9483	0.0733	-1.281013396	24.81444007
UllagePres	0.275004813	0.067714984	4.0612	0.0013	0.128715484	0.421294141
CycleTime	-29.46607337	9.404504049	-3.1332	0.0079	-49.78326915	-9.148877596
Step Information	**Multiple R**	**R-Square**	**Adjusted R-Square**	**StErr of Estimate**	**Enter or Exit**	
UllagePres	0.6992	0.4889	0.4523	0.836487017	Enter	
CycleTime	0.8419	0.7088	0.6640	0.655232234	Enter	

While this regression equates to an R^2 of 0.664, the somewhat lower significance than the proposed three-variable regression is balanced by the logic of using data points that are representative of the future configuration.

8.0 Findings, Root Causes, Observations and Recommendations

8.1 Findings

F-1. Using the same assumptions, regression results obtained during this review confirmed that the SSP regressions have included appropriate, and only the most appropriate, predictors in their regression.

F-2. A linear model is the correct choice for this regression and correctly captures the relationships in the data.

F-3. Use of the full data set provided is not justified since several of the independent variables reflected out-of-specification materials and components, which will not be repeated in the future. The reduced data set of 16 data points is adequate for regression with less than four independent variables.

8.2 Recommendations

R-1. Linear regression is an appropriate tool to validate the NASA-accredited analytical (first principles) model, currently under development, against empirical data available since the transition to half-second valve pulses. (F-1 and F-2)

R-2. Regression should be based on the reduced data set, excluding STS-114 tanking tests where the incorrect diffuser material was used and MLP-2 restricted flow was created from out-of-specification conditions, since these situations have been corrected. (F-3)

9.0 Lessons Learned

There were no lessons learned during this consultation.

10.0 Definition of Terms

Corrective Actions	Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a problem.

Finding	A conclusion based on facts established during the assessment/inspection by the investigating authority.
Lessons Learned	Knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. A lesson must be significant in that it has real or assumed impact on operations; valid in that it is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or limits the potential for failures and mishaps, or reinforces a positive result.
Observation	A factor, event, or circumstance identified during the assessment/inspection that did not contribute to the problem, but if left uncorrected has the potential to cause a mishap, injury, or increase the severity should a mishap occur.
Problem	The subject of the technical assessment/inspection.

11.0 Minority Report (Dissenting Opinions)

There were no dissenting opinions during this consultation.

Volume II: Appendices

A NESC ITA/I Request Form (NESC-PR-003-FM-01)
B Key for Interpreting Box Plots and Scatterplots
C List of Acronyms

Appendix A. NESC ITA/I Request Form (NESC-PR-003-FM-01)

NASA Engineering and Safety Center Request Form		
Submit this ITA/I Request, with associated artifacts attached, to: nrbexecsec@nasa.gov, or to NRB Executive Secretary, M/S 105, NASA Langley Research Center, Hampton, VA 23681		
Section 1: NESC Review Board (NRB) Executive Secretary Record of Receipt		
Received (mm/dd/yyyy h:mm am/pm) 9/20/2005 12:00 AM	Status: New	Reference #: 05-171-E
Initiator Name: Billy Stover	*E-mail:* Billy.R.Stover@nasa.gov	*Center:* KSC
Phone: (321)-861-8554, Ext _____	Mail Stop:	
Short Title: Data Expertise for Independent Verification for ET LH2 Prepress LCC Issues		

NESC Request Form
NESC-PR-003-FM-01, v1.0
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Description: Ralph ¬
Ref below .
The guys here are requesting our help in reviewing and validating a
>>regression analysis tool developed to predict ET pre-press cycles. This
>>relates to the LCC and the problems we had during STS-114 with the
>>unexpected cycle count.
>>We don't need to have the work completed until mid-November or so, but we
>>do need to be able to tell them whether or not we can assist before they
>>go to the SICB on October 18. Since we don't have another NRB scheduled
>>before then, I'm requesting out-of-board approval for this project as a
>>consultation. Primary need will be for statistical expertise. If you
>>give a go, I'll ask Dawn and Vickie to identify the experts and put a
>>plan of some kind together for presentation at an upcoming NRB.
Tim

>>From: Stover, Billy R
>>Sent: Friday, October 07, 2005 11:59 AM
>>To: Wilson, Timmy R
>>Subject: FW: Data Expertise Needed For ET LH2 Prepress LCC
>>
>>Hi Tim,
Here is the information and stuff that we would appreciate an independent
verification on.
Thanks,
Billy
From: Stees, Diane S
>>Sent: Thursday, October 06, 2005 3:33 PM
>>
>>To: Stover, Billy R
Subject: FW: Data Expertise Needed For ET LH2 Prepress LCC
Billy,
>>
>>This is the original email I sent to Lisa with additional data. Diane J

From: Stees, Diane S
Sent: Tuesday, October 04, 2005 4:30 PM
To: Huddleston, Lisa L
Subject: RE: Data Expertise Needed For ET LH2 Prepress LCC
Lisa,
Lisa,
Here are some files to get you started. This includes data matrices,
>>schematics, regression analysis and charts that explain how our s/w
>>counts prepress cycles for LCC ET-04. Let me know what else you need. Thanks!
>>
>><<LH2 MLPPrePressSumm.xls>> <<FW: PrePress Pitch>> <<PrePress
>>Regress>> <<LH2 Prepress.PPT>> <<STS-114 S0007 #2 LH2 Prepress.PPT>>
>><<STS-114 S0037-2 Prepress Test Cycle Count.ppt>> <<RE: He charts>>
>>
>>Diane Stees
>>
>>NASA ET Cryogenic Systems
>>
>>(321) 861-3938 OSB 5403H
>>
>>pager 232-6142 PH-G3
>>
>>____
>>
>>From: Huddleston, Lisa L
>>
>>Sent: Monday, October 03, 2005 4:46 PM
>>
>>To: Stees, Diane S
>>
>>Subject: RE: Data Expertise Needed For ET LH2 Prepress LCC
>>
>>Hi Diane,
>>
>>I would be happy to look at the data. I am on the Gap Fille
>>test project and have periodic breaks between experiments and meetings
>>where I can look at the data.
>>

NESC Request Form Page 2 of 5
NESC-PR-005-FM-01, v1.0

Source (e.g. email, phone call, posted on web): email		
Type of Request: consultation		
Proposed Need Date:		
Date forwarded to Systems Engineering Office (SEO): (mm/dd/yyyy h:mm am/pm):		
Section 2: Systems Engineering Office Screening		
Section 2.1 Potential ITA/I Identification		
Received by SEO: (mm/dd/yyyy h:mm am/pm): 10/7/2005 12:00 AM		
Potential ITA/I candidate? ☐Yes ☒ No		
Assigned Initial Evaluator (IE):		
Date assigned (mm/dd/yyyy):		
Due date for ITA/I Screening (mm/dd/yyyy):		
Section 2.2 Non-ITA/I Action		
Requires additional NESC action (non-ITA/I)? ☒Yes ☐ No		
If yes:		
Description of action: Data Review for Independent Verification		
Actionee: Tim Wilson to lead; approved Out-of-Board by Ralph Roe on 10/7/2005		
Is follow-up required? ☒Yes ☐ No If yes: Due Date:		
Follow-up status/date: Provide plan and status		
If no:		
NESC Director Concurrence (signature):		
Request closure date:		
Section 3: Initial Evaluation		
Received by IE: (mm/dd/yyyy h:mm am/pm):		
Screening complete date:		
Valid ITA/I candidate? ☐Yes ☐ No		
Initial Evaluation Report #: NESC-PN-		
Target NRB Review Date:		
Section 4: NRB Review and Disposition of NCE Response Report		
ITA/I Approved: ☐Yes ☐ No	Date Approved:	Priority: - Select -
ITA/I Lead: , Phone ( ) - , x		
Section 5: ITA/I Lead Planning, Conduct, and Reporting		
Plan Development Start Date:		
ITA/I Plan # NESC-PL-		
Plan Approval Date:		
ITA/I Start Date	Planned:	Actual:
ITA/I Completed Date:		
ITA/I Final Report #: NESC-PN-		
ITA/I Briefing Package #: NESC-PN-		
Follow-up Required? ☐Yes ☐ No		
Section 6: Follow-up		
Date Findings Briefed to Customer:		
Follow-up Accepted: ☐Yes ☐ No		
Follow-up Completed Date:		
Follow-up Report #: NESC-RP-		

NESC Request Form
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Page 3 of 5

Section 7: Disposition and Notification	
Notification type: - Select -	Details:
Date of Notification:	
Final Disposition: - Select -	
Rationale for Disposition:	
Close Out Review Date:	

Form Approval and Document Revision History

Approved: ______________________ NESC Director	________ Date

Version	Description of Revision	Office of Primary Responsibility	Effective Date
1.0	Initial Release	Principal Engineers Office	29 Jan 04

NESC Request Form
NESC-PR-003-FM-01, v1.0

Page 5 of 5

Appendix B. Key for Interpreting Box Plots and Scatterplots

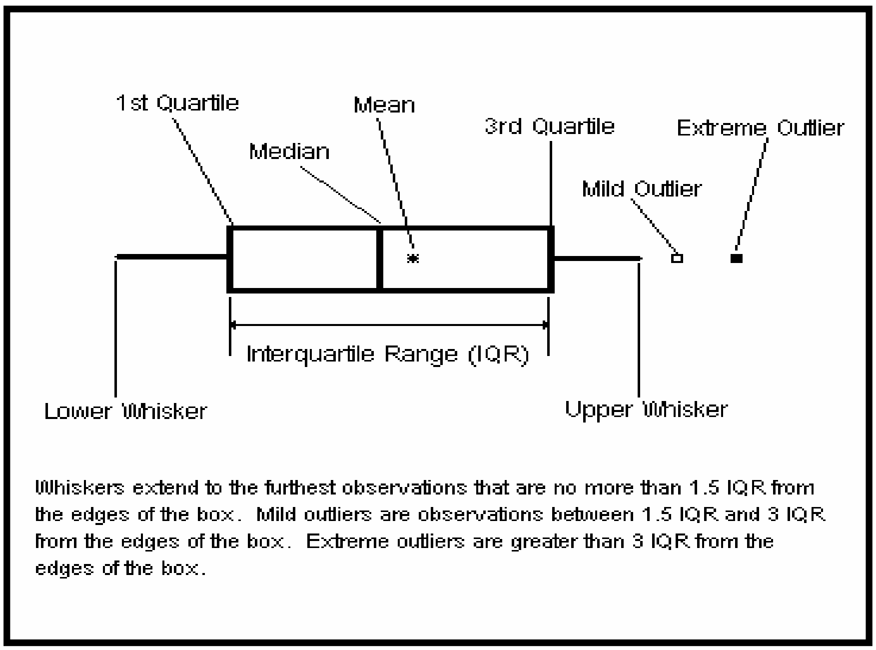
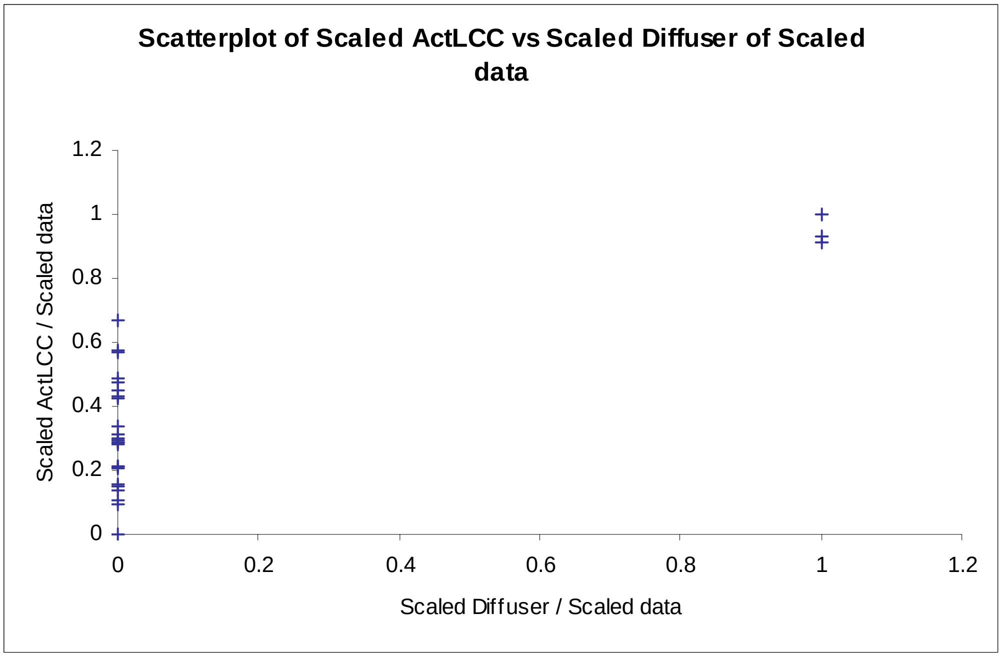
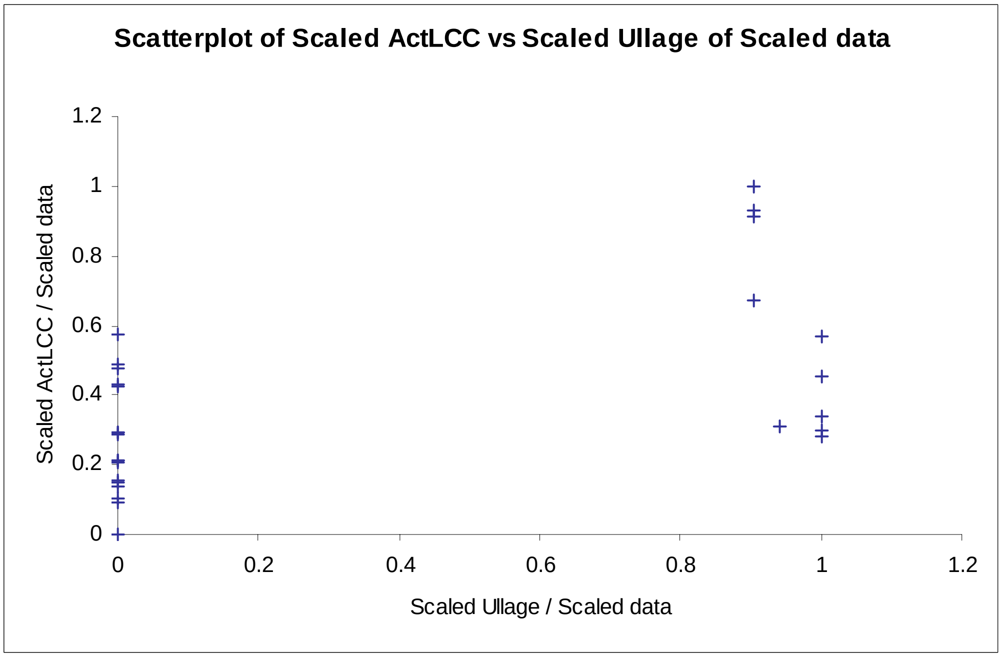


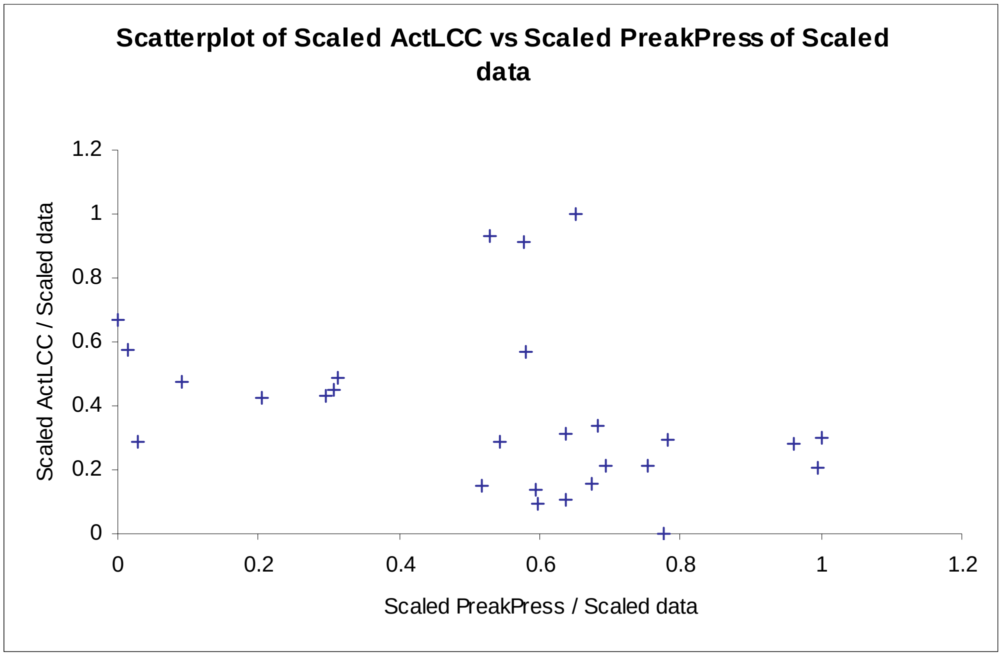
Figure B-1. Key for Interpreting Box Plots



B-2. Scatterplot for the Scaled Output and *Diffuser* Predictor



B-3. Scatterplot for the Scaled Output and *UllagePres* Predictor



B-4. Scatterplot for the Scaled Output and *PeakPres* Predictor

Appendix C. List of Acronyms

ET	External Tank
GHe	Gaseous Helium
GN_2	Gaseous Nitrogen
LaRC	Langley Research Center
LCC	Launch Commit Criteria
LH_2	Liquid Hydrogen
MLP	Mobile Launch Pad
MTSO	Management Technical and Support Office
NASA	National Aeronautics and Space Administration
NESC	NASA Engineering and Safety Center
NRB	NESC Review Board
SEO	Systems Engineering Office
SSP	Space Shuttle Program
STS	Space Transportation System

Approval and Document Revision History

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	NESC Director	Date

Version	Description of Revision	Office of Author	Effective Date
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14. ABSTRACT
The request to conduct an independent review of regression models, developed for determining the expected Launch Commit Criteria (LCC) External Tank (ET)-04 cycle count for the Space Shuttle ET tanking process, was submitted to the NASA Engineering and Safety Center NESC on September 20, 2005. The NESC team performed an independent review of regression models documented in Prepress Regression Analysis, Tom Clark and Angela Krenn, 10/27/05. This consultation consisted of a peer review by statistical experts of the proposed regression models provided in the Prepress Regression Analysis. This document is the consultation's final report.

15. SUBJECT TERMS
ET; LCC, NESC, SSP; STS

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(Include area code)*
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