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JUNE 28, 1974

ASYMMETRICAL BOOSTER ASCENT GUIDANCE AND CONTROL SYSTEM DESIGN STUDY

VOLUME III

SPACE SHUTTLE VEHICLE SRB ACTUATOR FAILURE STUDY

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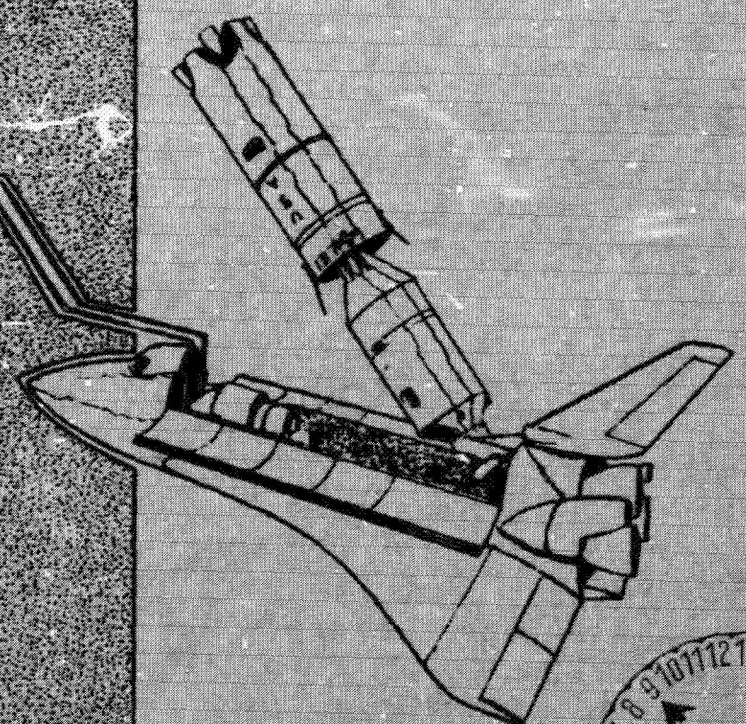

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ASYMMETRICAL BOOSTER ASCENT GUIDANCE AND CONTROL SYSTEM DESIGN STUDY

VOLUME III

SPACE SHUTTLE VEHICLE
SRB ACTUATOR FAILURE STUDY

JUNE 28, 1974

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PREFACE

Final report of Asymmetrical Booster Ascent Guidance and Control System Design Studies performed under Contract NAS9-13568 are contained in five separate volumes identified as follows:

Volume I - Summary
Volume II - SSFS Math Models - Ascent
Volume III - Space Shuttle Vehicle SRB Actuator Failure Study
Volume IV - Sampled Data Stability Analysis Program (SADSAP) - Users Guide
Volume V - Space Shuttle Powered Explicit Guidance

ABSTRACT

Volume III documents investigation of single actuator failures on the Solid Rocket Booster. Both square pattern (□) and diamond pattern (◇) actuator configurations were analyzed. It was determined that for failures occurring near or prior to the region of maximum dynamic pressure, control gain adjustments can be used to achieve virtually nominal mid-boost vehicle behavior. However, near staging, a distinct worst case failure condition was established that could significantly delay staging. It is recommended that the square pattern be retained as a viable alternative to the baseline diamond pattern because the staging transient is better controlled resulting in earlier staging.

KEY WORDS

Booster Actuator Failure
Actuator Failure
Flight Dynamics
Shuttle Boost Dynamics
Space Shuttle Boost

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REFERENCES

1. "Space Shuttle Mass Properties Status Report", SD 72-SH-120-11, Aug. 2, 1973.

2. "Aerodynamic Design Data Book - Vol. II Integrated Vehicle", SD 72-SH-0060-2D, June 1973.

3. "Space Shuttle Guidance and Control Data Book", SD 73-SH-0097A, July 13, 1973.

NOMENCLATURE

ETR	Eastern Test Range
FT-LBS	Foot Pounds
JSC	Lyndon B. Johnson Space Center
M/S	Meters Per Second
NASA	National Aeronautics and Space Administration
PSF	Pounds Per Square Foot
Q	Dynamic Pressure
$Q\alpha$, $Q\text{-}\alpha$	Dynamic Pressure Times Angle of Attack
$Q\beta$, $Q\text{-}\beta$	Dynamic Pressure Times Sideslip Angle
Q_{max}	Maximum Dynamic Pressure
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SSME	Space Shuttle Main Engine
TVC	Thrust Vector Control
VAFB	Vandenberg Air Force Base
α	Angle of Attack
β	Sideslip Angle

1.0 INTRODUCTION AND SUMMARY

Studies have been conducted investigating the performance of the Configuration IV Space Shuttle vehicle with one solid rocket motor TVC actuator failure. Primary study objectives were to determine design cases (worst conditions) for the baseline TVC actuator configuration (45° - 135° orientation) and the 0° - 90° TVC (pitch-yaw) configuration.

Simulations were performed, individually failing each of the four solid rocket booster (SRB) actuators. Several failure times were tested, from liftoff to the region of maximum dynamic pressure (Q_{max}). Thrust unbalance between the two SRM's was simulated and the effect of headwinds, tailwinds and crosswinds was investigated. Staging criteria were implemented in the simulation. Nominal staging for this configuration occurs at 123 seconds from liftoff. All simulation runs that failed to meet the staging criteria were terminated at 140 seconds.

It was determined that the worst case design conditions for this vehicle configuration are those summarized in Figure 1. For those mid-boost conditions (liftoff to beyond Max Q) the loads indicator, dynamic pressure times sideslip angle ($Q\beta$) was significantly higher than for other simulation cases. Satisfactory compensation was achieved for the mid-boost cases.

At thrust tailoff the thrust unbalance between the SRM's caused a yaw transient that significantly delayed the staging time. For the 45° - 135° TVC actuator configuration, adverse roll-yaw torque from the remaining thrusting actuator precluded successful compensation; but for the 0° - 90° TVC configuration, compensation permitted some reduction of the delay in staging.

It is recommended that the 0° - 90° TVC actuator configuration be retained as a viable alternative to the baseline 45° - 135° TVC configuration and that additional studies be performed on staging compensation. It is also recommended that load relief studies be initiated to develop techniques for decreasing the effect of actuator failures and winds on vehicle loads during boost.

DESIGN CONDITIONS

		SRM WITH HIGH THRUST	SRM WITH FAILED ACTUATOR	ACTUATOR FAILED	WIND
45^0 - 135^0 BASELINE ACTUATOR CONFIGURATION	MID-BOOST	LEEWARD	WINDWARD	LEFT	RIGHT CROSS
				RIGHT	LEFT CROSS
	TAILOFF	WINDWARD	WINDWARD	LEFT	RIGHT CROSS
				RIGHT	LEFT CROSS
0^0 - 90^0 ACTUATOR CONFIGURATION	MID-BOOST	LEEWARD	WINDWARD	PITCH	CROSSWIND
	TAILOFF	WINDWARD	WINDWARD	YAW	CROSSWIND

- ACTUATOR FAILURES AT LIFTOFF PRODUCE LARGEST PERTURBATIONS.

FIGURE 1 DESIGN CONDITIONS

2.0 STUDY PARAMETERS

The Space Shuttle configuration studied was the VL72-000088B configuration IV vehicle described in references 1 through 3. Simulations were performed, separately failing each of the four solid rocket booster (SRB) actuators. An actuator failure was simulated by commanding it to null at its rate limit (3 degrees per second for this study). Failure times were selected at:

1) liftoff,
2) 8 seconds (beginning of roll maneuver),
3) 28 seconds (end of roll maneuver), and
4) 57 and 58 seconds (during the region of the wind gust).

In the initial study phase no changes were made to the control system gains or mixing logic in order to compensate for the actuator loss. Then, after determining the effects of the failures, compensation techniques were investigated to minimize deviations from nominal.

For all simulations thrust unbalance between the two SRM's was set at ±0.98% because this resulted in the specification limit of 450,000 lbs thrust differential at tailoff. The thrust profile of each SRM and the thrust differential resulting from a ±0.98% mismatch is shown in Figure 2. The high thrust motor burns faster, thus burning out sooner resulting in higher thrust on the "low thrust" motor during the thrust tailoff region. No angular misalignments were introduced in any of the Space Shuttle Main Engines (SSME) actuators or SRB actuators.

Synthetic directional design wind profiles were generated and applied to the vehicle as headwind, tailwind, and right crosswinds. The tailwind and crosswind profiles were 95 percentile winds during the gust region and were modified to 1σ winds (34% above the 50 percentile profile) during the SRB tailoff region. The headwind profile was used as a 95 percentile profile throughout the flight. The gust attitude for these winds was selected at 10 KM, which coincides with the time of maximum dynamic pressure. These three wind profiles are shown in Figures 3-5.

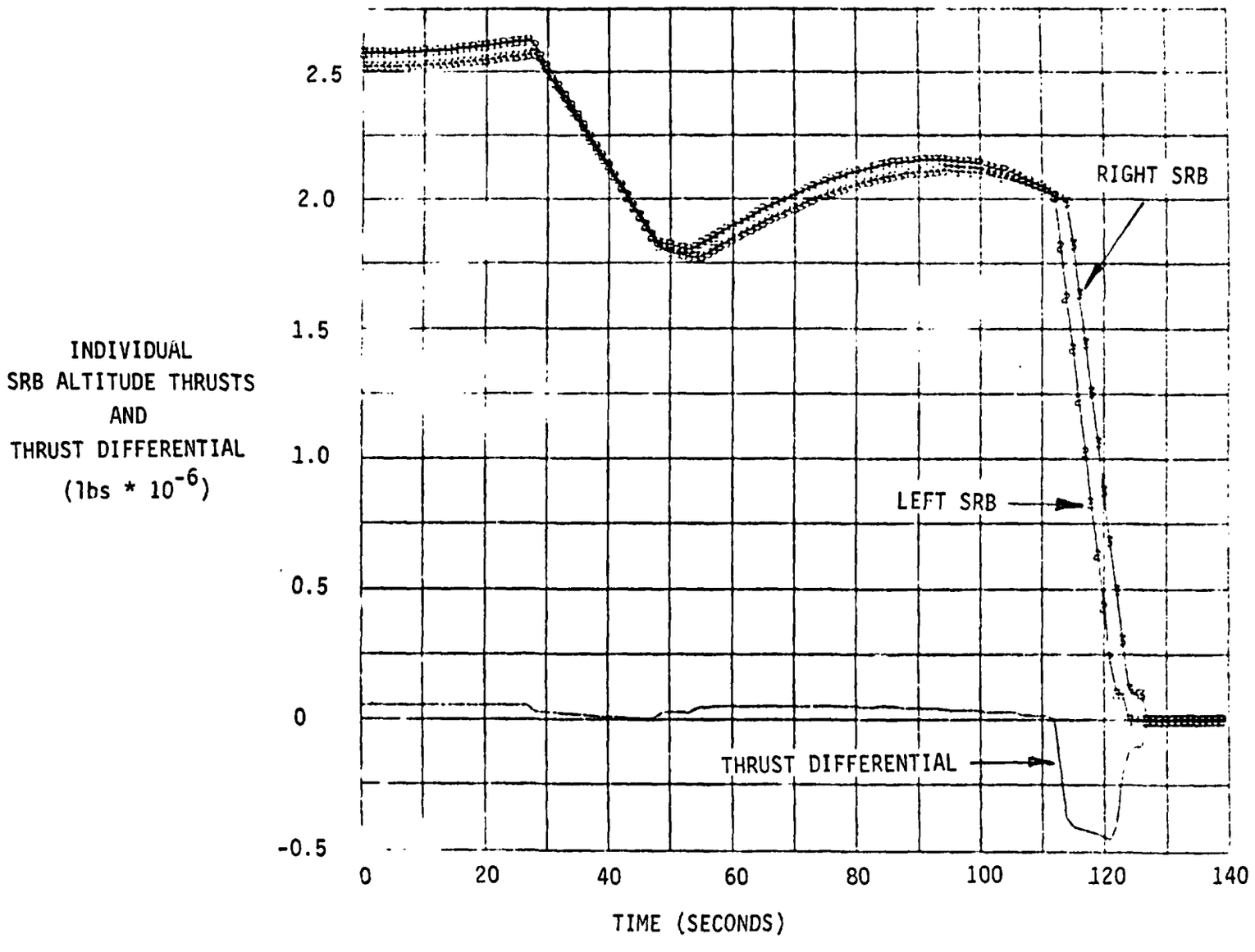


FIGURE 2 0.98% MISMATCH THRUSTS VERSUS TIME

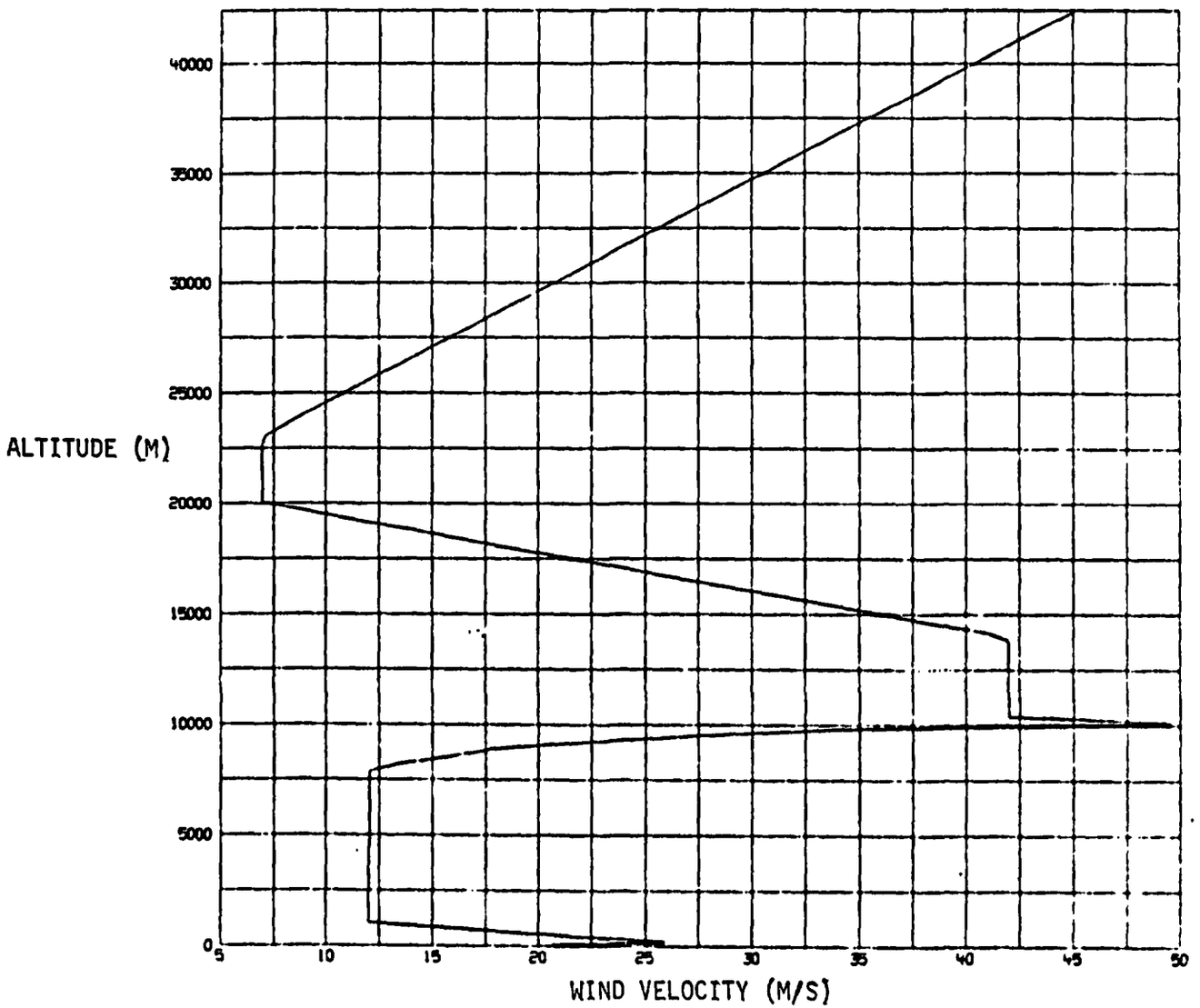


FIGURE 3 VAFB 42 M/S HEADWIND

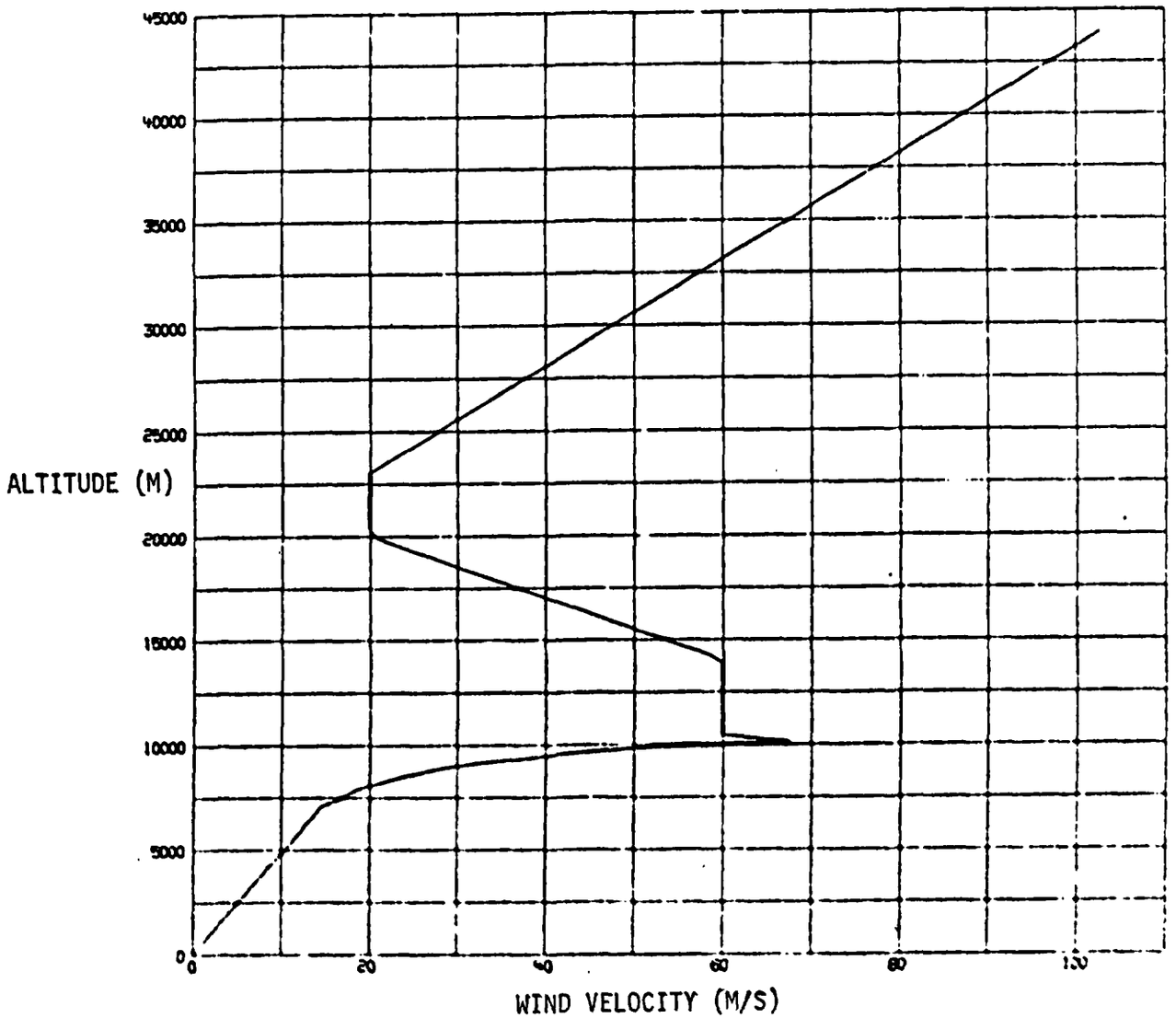


FIGURE 4 VAFB 60 M/S CROSSWIND (MODIFIED)

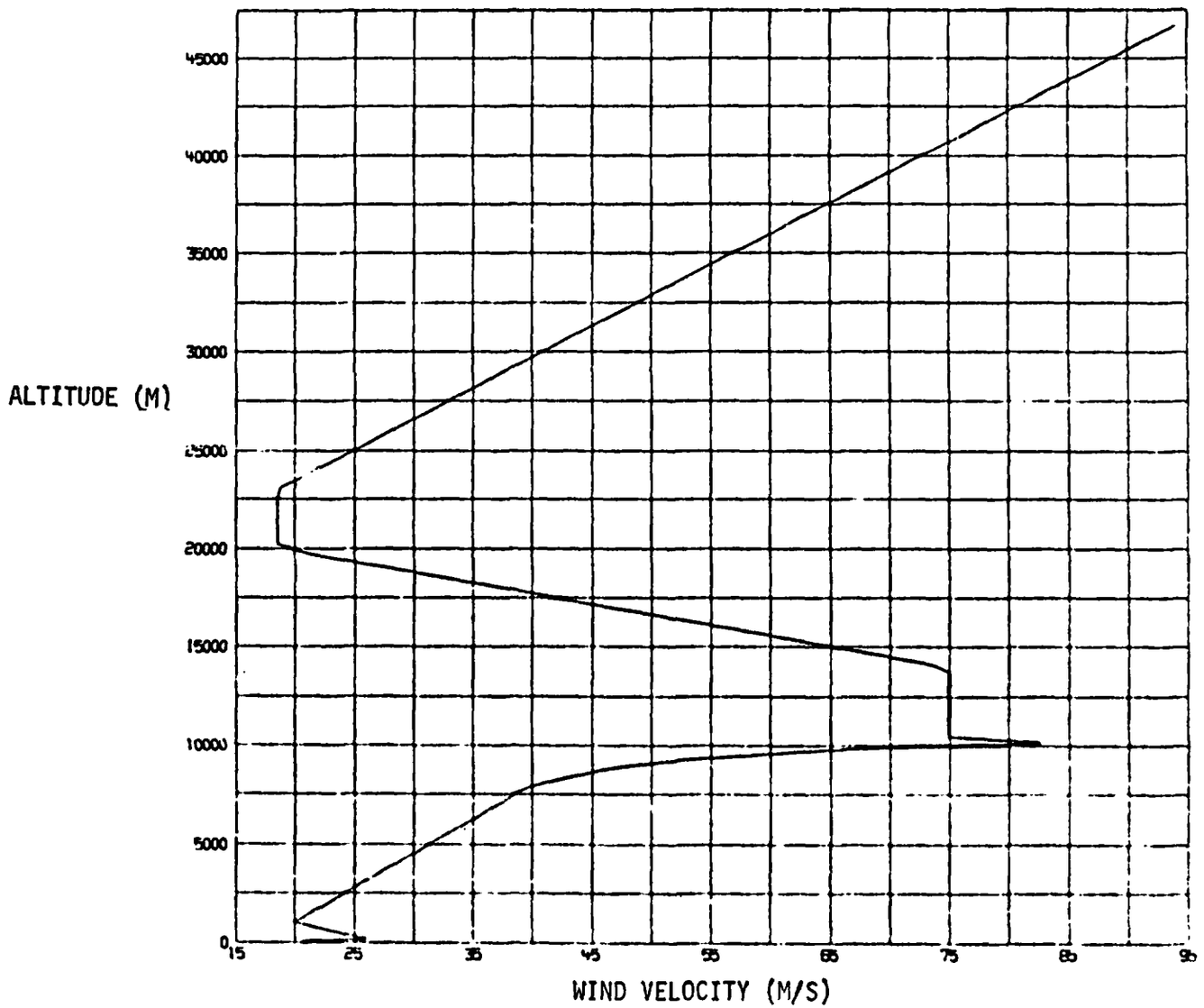


FIGURE 5 ETR 75M/S TAILWIND (MODIFIED)

Staging criteria for the simulations were implemented such that staging was not allowed to occur until all criteria were met. The staging criteria used in this study were:

1) thrust on the highest thrust SRM must be less than 100,000 lbs,
2) sideslip must be less than ±5 degrees,
3) body roll rate must be less than ±10 degrees per second, and
4) body pitch and yaw rates must be less than ±2 degrees per second.

A limit on angle-of-attack was not imposed for these cases since minor trajectory anomalies cause all cases to slightly exceed ±5 degrees angle-of-attack at staging. All runs were terminated at 140 seconds if staging criteria were not met by that time.

3.0 45° - 135° TVC ACTUATOR CONFIGURATION STUDIES

3.1 Design Conditions

Worst case design conditions determined from this study are summarized in Figure 1. During the mid-boost region of flight most severe conditions are felt in the presence of a crosswind with the leeward SRM with high thrust and the actuator failure on the windward SRM. For right crosswinds the more severe case is with the left actuator failed. For left crosswinds it is with right actuator failures on the windward motor.

During the tailoff portion of boost, design conditions were found to be with crosswinds with high thrust on the windward SRM and with the actuator failure occurring also on this motor. For right crosswinds the most severe condition arises with a left actuator failure on the windward motor; for left crosswinds, with a right actuator failure on this motor.

3.2 Discussion of Results

The design conditions described in section 3.1 were the result of approximately 80 simulation cases. Figure 6 is a run matrix of the simulations performed in this study. More failure times were selected within the crosswind column for it was felt that this wind was the most severe w.r.t. vehicle control during boost. Two failure times were included within the headwind column, one at liftoff and one at 28 seconds (during the end of the roll maneuvers). For each of four actuator failures within a wind column each case was run with both orientations of SRB thrust mismatch.

Complete detailed results of all simulations are contained within Appendix A1 and A2. Appendix A1 is a collection of tables of results of maximum values during boost. Tabulated in these tables are maximum dynamic pressure, $q\alpha$, $q\beta$, body attitude errors, and body rates. Appendix A2 is a summary of conditions at staging. Included are dynamic pressure, angle-of-attack, sideslip angle, Mach No., body attitude rates, and SRM duty cycles. Also tabulated are the times at which staging criteria were achieved. Detailed discussions of these results will be separated into mid-flight results and separation results.

THRUST MISMATCH *		WINDS: NO WIND +	NO WIND −	HEADWIND +	HEADWIND −	TAILWIND +	TAILWIND −	RIGHT CROSSWIND +	RIGHT CROSSWIND −
RIGHT ACT. ON LEFT MTR FAIL (TIME IN SEC)	0	▩	▩	▩	▩	▩	▩	▩	▩
	8							▩	▩
	28			▩	▩			▩	▩
	56								
	57								
	58							▩	▩
	60								
LEFT ACT. ON LEFT MTR FAIL	0	▩	▩	▩	▩	▩	▩	▩	▩
	8							▩	▩
	28			▩	▩			▩	▩
	56								
	57								
	58							▩	▩
	60								
RIGHT ACT. ON RIGHT MTR FAIL	0	▩	▩	▩	▩	▩	▩	▩	▩
	8							▩	▩
	28			▩	▩			▩	▩
	56								
	57								
	58							▩	▩
	60								
LEFT ACT. ON RIGHT MTR FAIL	0	▩	▩	▩	▩	▩	▩	▩	▩
	8							▩	▩
	28			▩	▩			▩	▩
	56								
	57								
	58							▩	▩
	60								

* + = LEFT SRM "HOT", − = RIGHT SRM "HOT"

▩ INDICATES RUNS ACCEPTABLE

FIGURE 6 RUN MATRIX 45°-135° TVC BASELINE ACTUATOR SYSTEM - UNCOMPENSATED

3.2.1 Mid-Boost Results

In general, the effect of an SRB actuator failure had minimal impact on vehicle control during the mid-boost region of flight. The effects of wind azimuth were most noticed in the load parameters, dynamic pressure (Q), $Q\alpha$, and $Q\beta$. Whereas, maximum dynamic pressure averaged approximately 650 psf for the no-wind cases the headwind studies showed max Q's on the order of 750 psf, and tailwinds ran approximately 600 psf. Crosswind cases averaged approximately 1900-2000 psf° for $Q\alpha$. Maximum $Q\beta$ occurred with the crosswind simulations. Peak $Q\beta$'s of +4500 were observed for one of the actuator failure conditions. Headwind simulations were the next most severe with respect to $Q\beta$. Values of +2300 psf° were observed for the headwind cases. Tailwind and no-wind simulations were the least severe with values of 1000 to 1500 psf° being observed.

Body attitude errors and rates were affected by the wind azimuth in that pitch errors were biased as a result of head or tailwinds. Crosswinds affected attitude errors primarily during the tailoff region. This will be discussed in the following section. Body rates during the mid-boost region of flight were in no case excessive nor significantly dependent upon wind azimuth.

Little difference between actuator failures was observed during the mid-boost region indicating that per se neither a right nor left actuator failure was more severe than the other. This is reasonable due to the 45° - 135° diagonal SRB actuator orientation, which eliminates the dependence of a single actuator axis on one axis of control. Likewise, only minor differences were seen between the failure of an actuator on the right SRM or the left SRM.

The results of having high thrust on either the right or left SRM was observed to influence the load parameters. Those cases with high thrust on the left SRM were found to have slightly higher ($\approx$ 1%) maximum dynamic pressures. The primary cause of this is the roll maneuver taking place during the pitch over command, and more precisely the direction of the roll maneuver. As the vehicle rolls clockwise and begins to pitch over the left SRM is to the outside of the pitch trajectory. With high thrust on this motor, the trajectory is

essentially biased toward a lower altitude, resulting in a higher Q flight. In addition, for flights in the presence of crosswinds, if the windward SRM has high thrust, this will aggravate any high sideslip condition already present.

The time of actuator failure was found to have little effect on any of the performance or control parameters. Duty cycle, however, was found to be affected and will be covered in the following section.

As an outgrowth of the Eighth Flight Control Panel Meeting of 28 February 1974, an action item was taken to supply Rockwell International (RI) with envelopes of maximum SSME actuator deflections occurring during flights with an SRB actuator failure. This data was prepared and forwarded to RI via the NASA JSC technical monitor. This data is included in this report in Appendix B1.

3.2.2 Thrust Tailoff Results

Greatest impact of loss of an SRB actuator was felt during the thrust tailoff region of flight. The prime contributor to control problems during this time is the SRB mismatch. During this time, as seen in Figure 2, the peak thrust mismatch of 450,000 lb occurs, producing approximately 9×10^6 ft-lbs of yaw torque. This perturbation combined with specific actuator failure and wind azimuths produce severe conditions at the nominal staging time.

The effect of wind azimuth was found, in general, to be more pronounced for a crosswind azimuth. Due to the magnitude of the ETR tailwind its effects were observed to influence body angular rates at staging, but in general were not "design cases". Headwinds, being of such low velocity, were not important at staging.

The time of actuator failure has no effect on staging conditions other than on SRB actuator duty cycle. Failures at liftoff, as would be expected, had larger duty cycles than failures at later times. As a separate study, individual actuator duty cycles were collected for various wind and thrust mismatch combinations, for both no failure trajectories and design case failures. In addition, comparisons were made between systems with and without failure mode compensation logic. This data has been previously informally transferred to the NASA/JSC technical monitor and is included in this report under Appendix B2.

The effect of which one of the four actuators failed and the effect of which SRB has high thrust are interrelated. The motor that has been burning "hot" throughout the boost will burn out before the other motor. Thus, it is obvious from a control standpoint that the worst failure would be a failure of one of the actuators on the motor that still has thrust. This will leave control on only one thrusting actuator. In addition the choice of which of the two actuators on the thrusting engine is failed is found to make considerable difference.

Referring to Figure 7, let us assume that we have had a "hot" burn of the left SRM during boost. This creates a negative yaw perturbation during the thrust tailoff region, and is shown on the drawing as the "thrust mismatch component". This negative yaw in turn creates a positive sideslip which aerodynamically introduces negative roll ("resulting aerodynamic component" on drawing). The sum of these torques is the vector representing the "thrust tailoff perturbation torque". Shown also on the drawing are representations of the envelopes of control torque available from each actuator on the right SRM. Due to the 45° - 135° diagonal orientation of the actuator, control via the right actuator moves from "+yaw - roll" to "-yaw + roll". Likewise, the left actuator control moves from "+roll + yaw" to "-roll - yaw". Thus to overcome the perturbation torque of a "hot" left SRM, the left actuator on the right SRM is correctly oriented to perform this function. However, if this actuator is failed, and the only remaining functioning actuator is the right actuator of the right SRM, then the control torque vector from this motor will aggravate the error conditions existing.

As was mentioned earlier, if a crosswind is present at thrust tailoff, its relationship to the "hot" SRM is important. For the worst case actuator failure conditions, if the crosswind was such that it effectively increased the sideslip angle that was being produced by the thrust yaw disturbance, then staging conditions became worse. On Figure 7 this has the effect of increasing the "resulting aerodynamic component" vector. Roll errors at staging with a favorable crosswind were -35 degrees, whereas with an unfavorable crosswind roll errors of -67 degrees were observed.

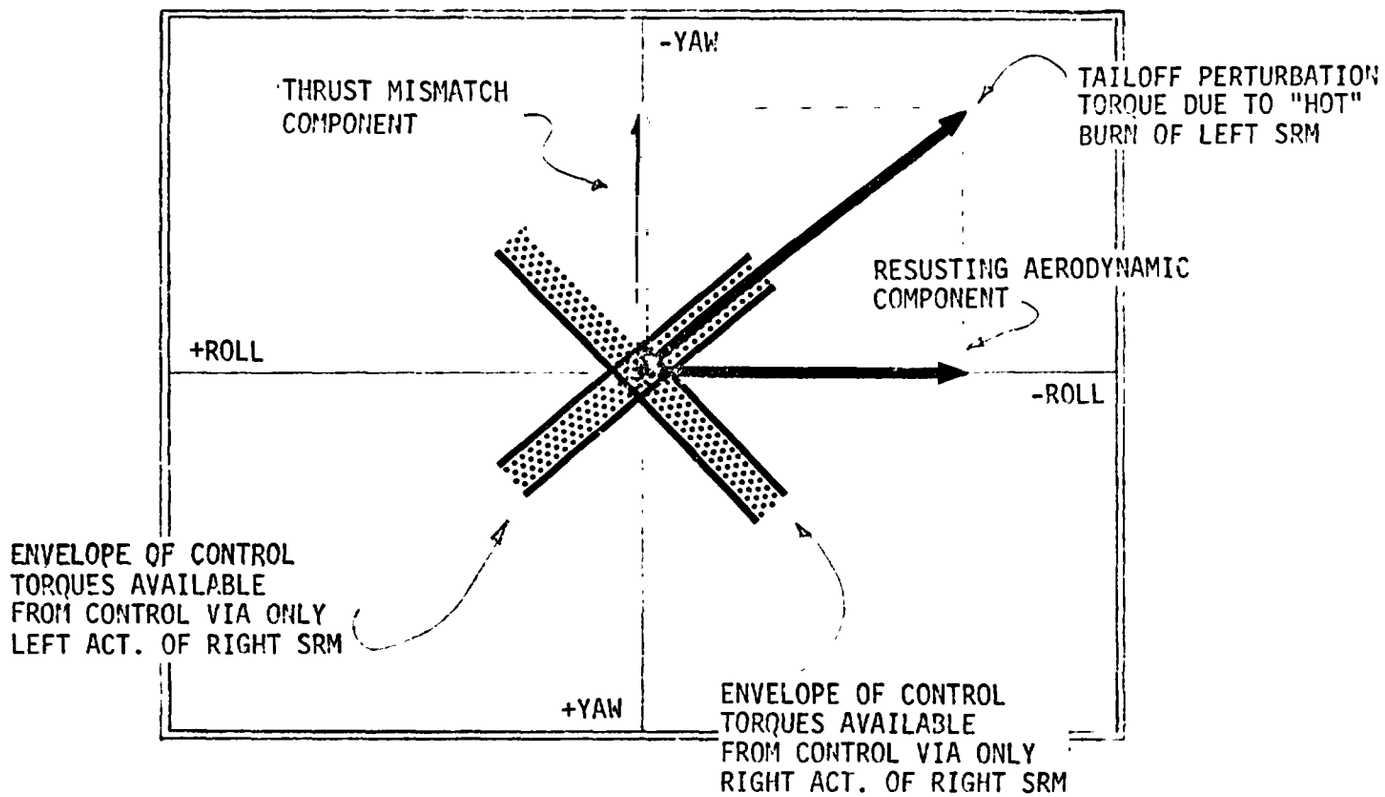


FIGURE 7 - ILLUSTRATION OF THRUST TAILOFF CONTROL AVAILABILITY

Plots of sideslip angle, Q-β, body roll and yaw rates, and body roll and yaw errors are shown in Figures 8 through 13. These plots are of a simulation with the failure of the left actuator on the right SRM with a "hot" left SRM and a right crosswind. Illustrated here are the dramatic tailoff transients.

3.2.3 Compensation Logic

Compensation logic for the baseline actuator system was successful for the mid-boost region of flight. This logic is shown in Figure 14. After an SRB actuator failure is detected, the SRB mixing logic is altered as shown. Roll commands to the SRM's are shifted to the same actuators (i.e., right actuator on left motor, right actuator on right motor, or vice versa) on each motor, avoiding the failed actuator. Pitch commands are routed to opposite actuators on each motor (left actuator on left motor, right actuator on right motor or vice versa). Yaw commands are placed only in the SRM without an actuator failure. In all cases the SRB gains are increased. SSME logic was left unchanged.

Attempts at SRM actuator failure compensation logic during the tailoff region to date have been unsuccessful. As described in the previous section worst case conditions occur during tailoff when the actuator failure has occurred on the SRM with remaining thrust. Under these circumstances only one SRB actuator remains with control authority and its control orientation is such that it will only aggravate conditions. It is clear that to avoid this worst case, at the time thrust is lost or significantly decreased on the unfailed SRM (actuator) that all control must be removed from the SRM's, and SSME TVC be utilized to maintain control through staging. Numerous methods of altering nominal first stage SSME logic while nulling the SRM's were tried. None were successful. At best yaw could be "traded" for roll. Control from the SSME's is not adequate to handle the effects of the yaw perturbation from thrust mismatch at tailoff, and excessive sideslip angles prevented staging. Data from three sets of runs is included for reference in Appendix A3. Both mid-boost data and conditions at staging are presented.

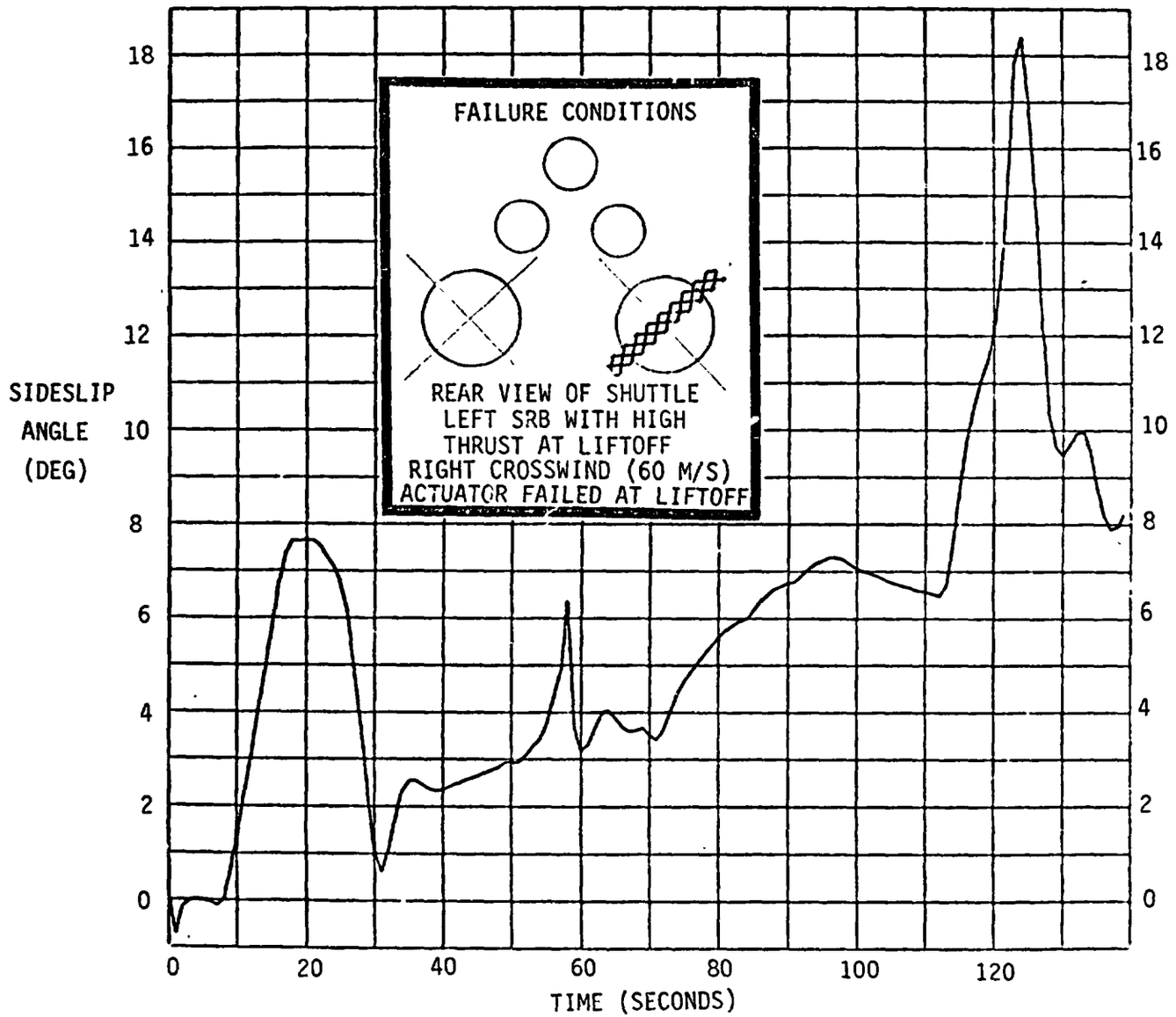


FIGURE 8 BASELINE SYSTEM - NO COMPENSATION
SIDESLIP ANGLE VERSUS TIME

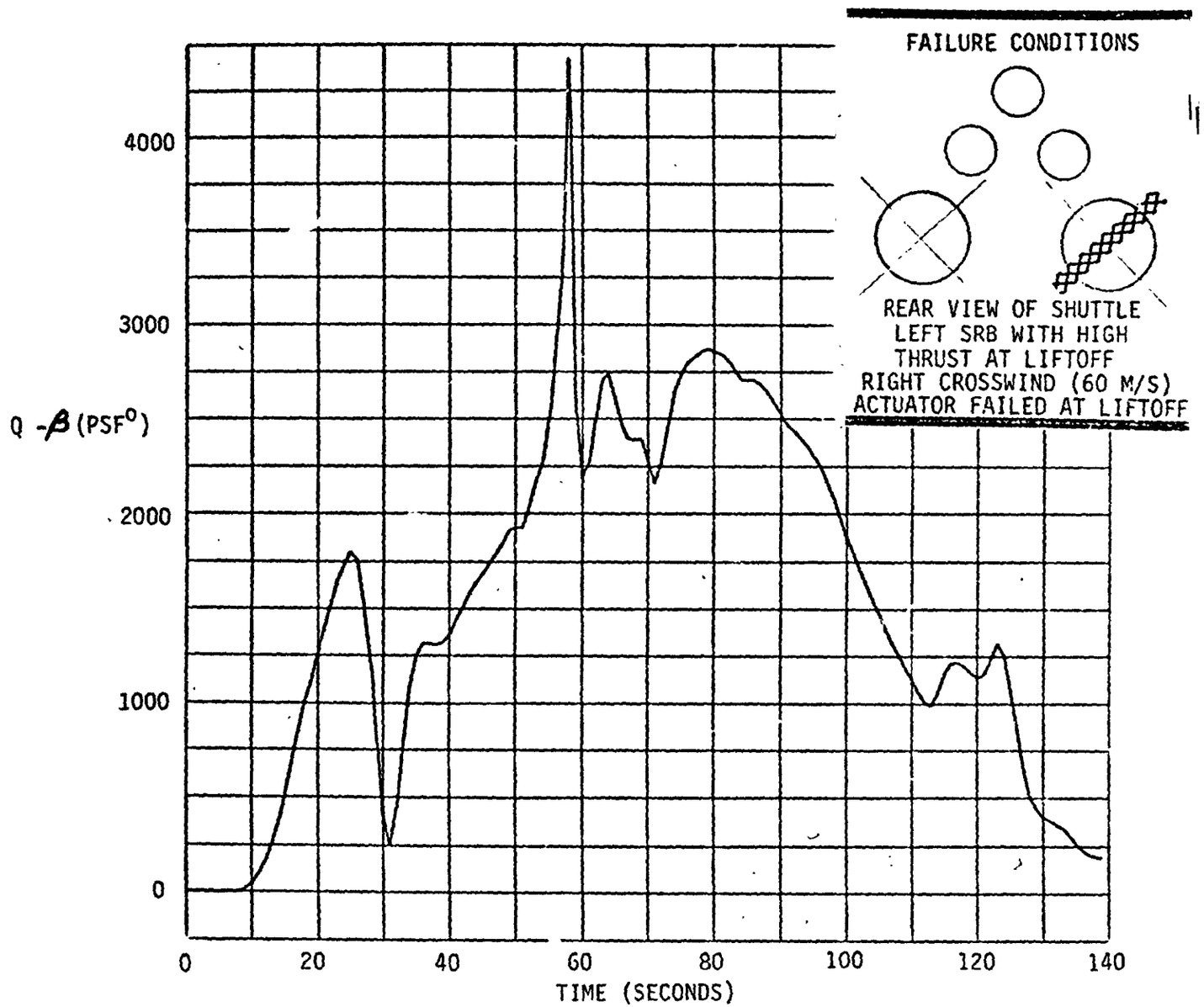


FIGURE 9 BASELINE SYSTEM - NO COMPENSATION
Q - β VERSUS TIME

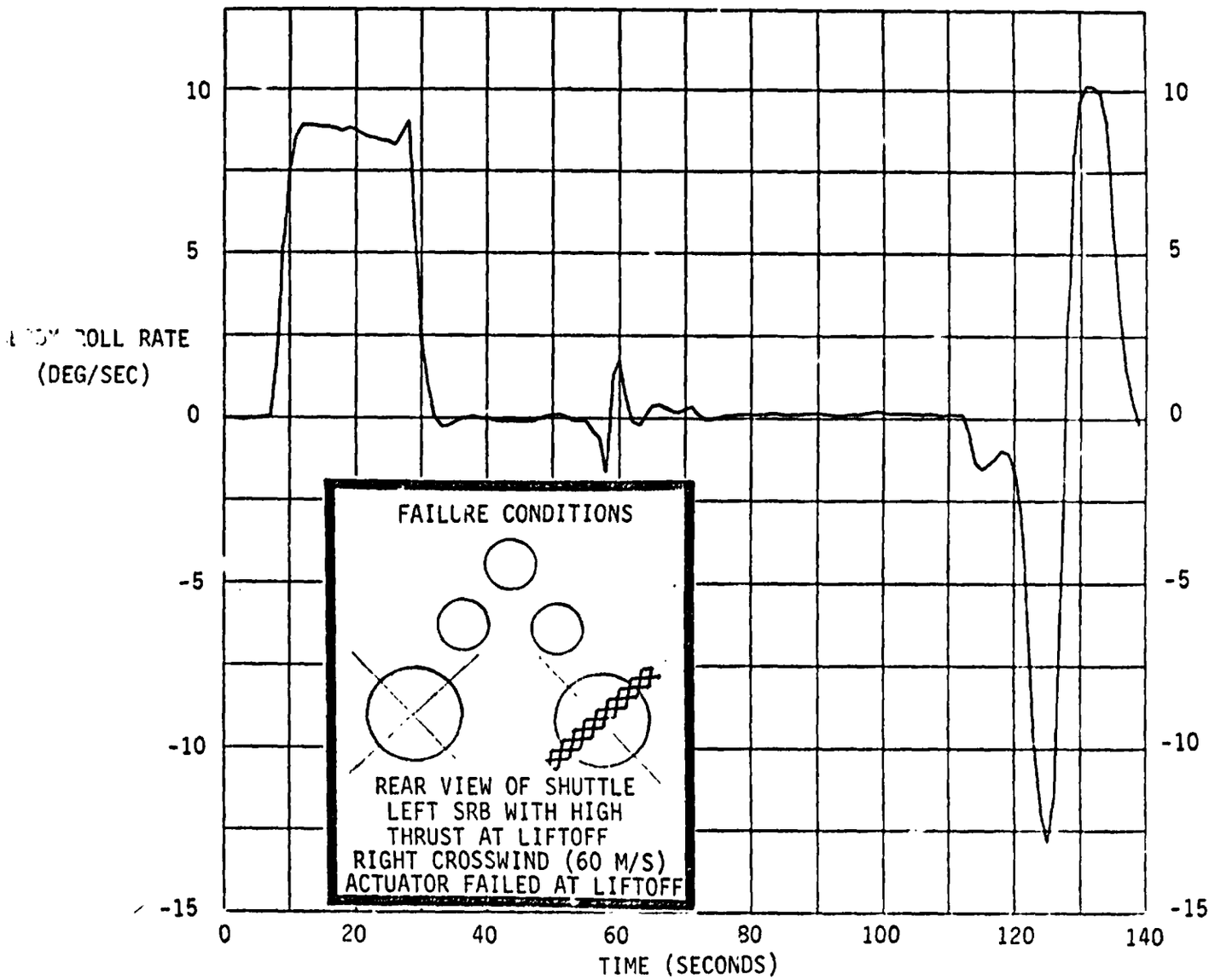


FIGURE 10 BASELINE SYSTEM - NO COMPENSATION
BODY ROLL RATE VERSUS TIME

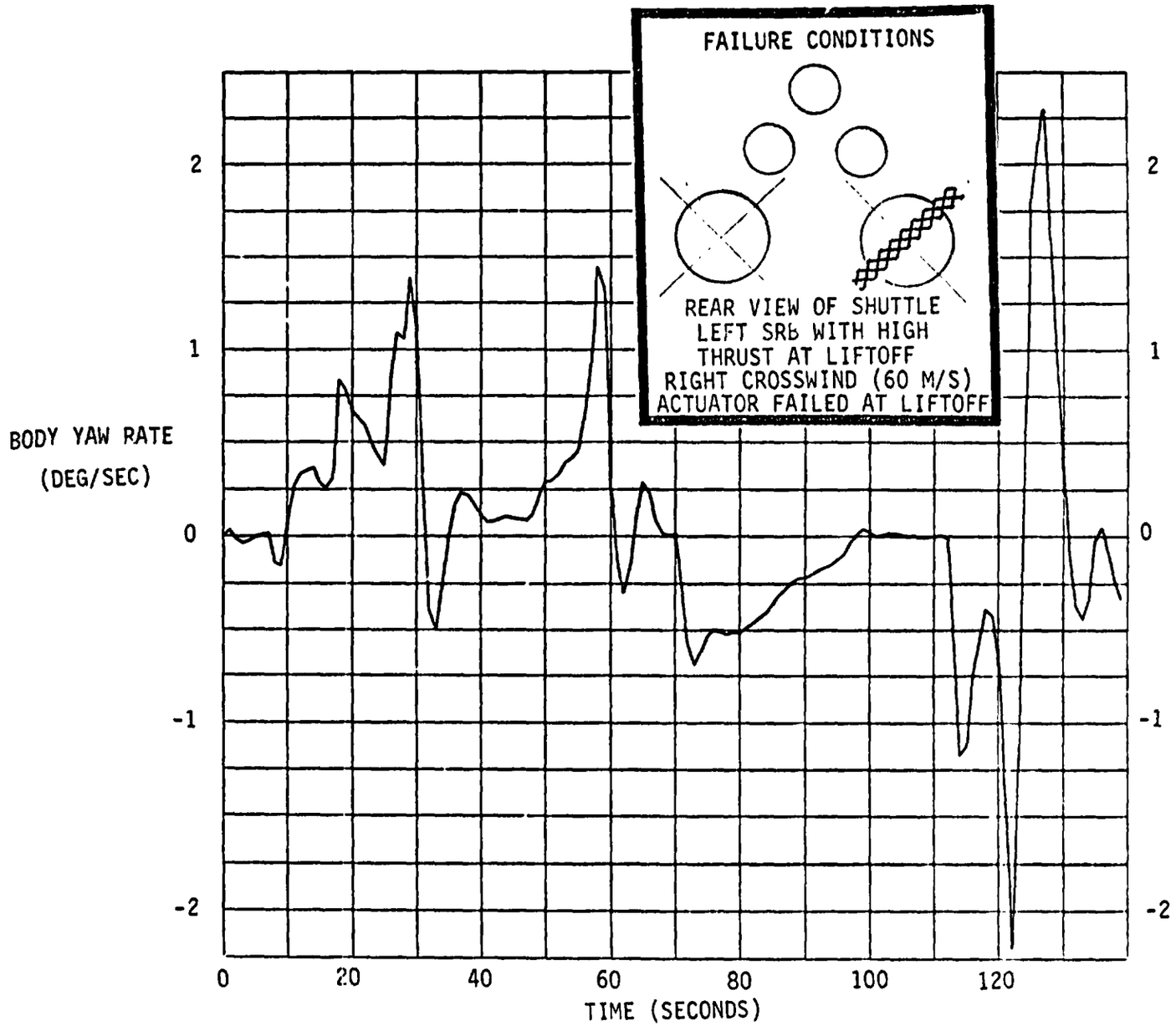


FIGURE 11 BASELINE SYSTEM - NO COMPENSATION
BODY YAW RATE VERSUS TIME

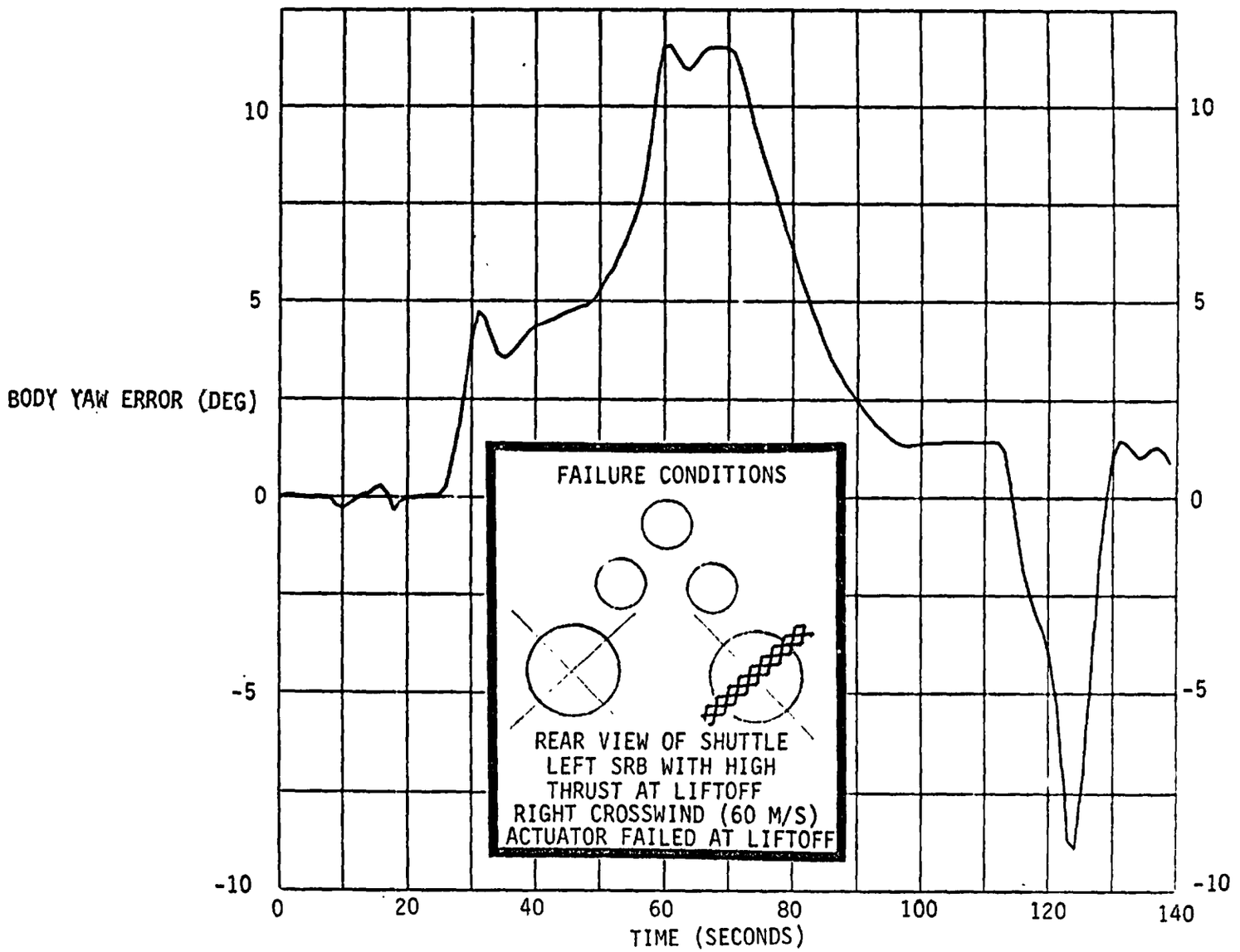


FIGURE 12 BASELINE SYSTEM - NO COMPENSATION
BODY YAW ERROR VERSUS TIME

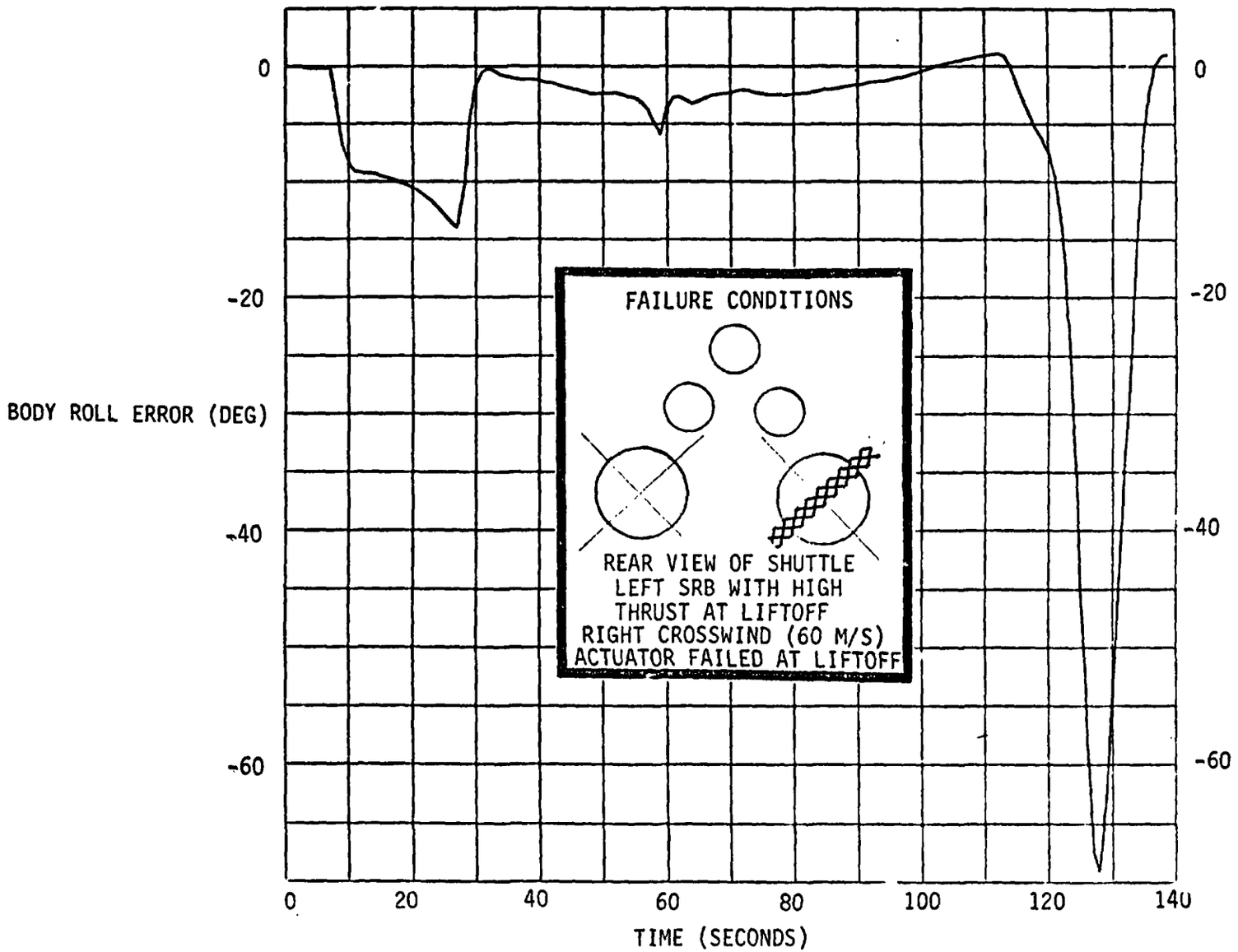
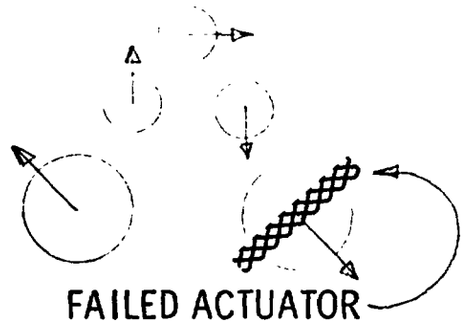


FIGURE 13 BASELINE SYSTEM - NO COMPENSATION
BODY ROLL ERROR VERSUS TIME

MID-BOOST LOGIC FOR 45° - 135° BASELINE ACTUATOR ORIENTATION

LEFT ACTUATOR FAILURES

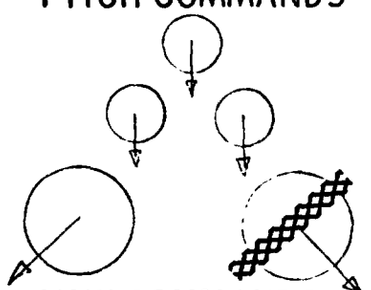
ROLL COMMANDS



SSME REMAINS UNCHANGED

BOOST SRB GAINS BY 1.4, AND APPLY COMMAND TO SAME ACTUATOR ON OPPOSITE ENGINE

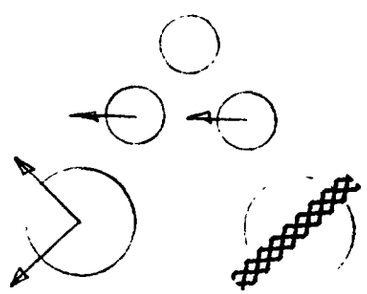
PITCH COMMANDS



SSME REMAINS UNCHANGED

BOOST SRB GAINS BY 1.4, AND APPLY COMMAND TO OPPOSITE ACTUATOR ON OPPOSITE ENGINE

YAW COMMANDS



SSME REMAINS UNCHANGED

BOOST SRB GAIN BY 2, AND APPLY ONLY TO ENGINE WITH UNFAILED ACTUATOR

FIGURE 14 MID-BOOST COMPENSATION LOGIC FOR 45°-135° BASELINE TVC SYSTEM

4.0 0° - 90° TVC ACTUATOR CONFIGURATION STUDIES

4.1 Design Conditions

Worst case design conditions for this configuration were also summarized in Figure 1. The most severe conditions were encountered in a crosswind, both during mid-boost and in the thrust tailoff region.

During boost, especially before and during the roll maneuver, a pitch actuator failure produced the worst conditions, while a yaw actuator failure resulted in virtually zero deviations from nominal. Specifically, failure of the pitch actuator on what becomes the windward side following the roll maneuver was the worst case, with high thrust on the opposite SRM causing slightly higher $Q\beta$.

At thrust tailoff, the worst case was failure of the yaw actuator on the windward side combined with high thrust on the same side at tailoff (meaning it was the low thrust motor at liftoff and so it has propellant remaining after the other motor has burned out).

The design conditions described above were obtained from simulations described in the run matrix shown in Figure 15. Simulations were performed with failure times of 0 and 57 seconds with both orientations of thrust mismatch and for headwind, crosswind, tailwind, and no wind environments. Results of the simulations are contained in Appendix A4 and A5. Appendix A4 contains mid-boost data for the 0° - 90° actuator system and Appendix A5 contains tailoff data. These results will be discussed in more detail in the following sections.

4.2 Discussion of Results

4.2.1 Mid-Boost Results

Yaw actuator failures did not cause significant deviations from nominal flight. Failure of the pitch actuator on the left SRM produced relatively minor effects, most notable of which was an increased roll lag during the roll maneuver. However, failure early in flight of the pitch actuator on the right SRM resulted in significant perturbations. The adverse coupling of roll and pitch commands to the remaining pitch actuator caused a large roll error during the roll maneuver.

		WINDS							
		NO WIND		HEADWIND		TAILWIND		RIGHT CROSSWIND	
THRUST MISMATCH *		+	−	+	−	+	−	+	−
PITCH ACT. ON LEFT MTR FAIL (TIME IN SEC)	0	▨	▨	▨	▨	▨	▨	▨	▨
	8								
	28								
	56								
	57			▨	▨	▨	▨	▨	▨
	58								
	60								
YAW ACT. ON LEFT MTR FAIL	0	▨	▨	▨	▨	▨	▨	▨	▨
	8								
	28								
	56								
	57			▨	▨	▨	▨	▨	▨
	58								
	60								
PITCH ACT. ON RIGHT MTR FAIL	0	▨	▨	▨	▨	▨	▨	▨	▨
	8								
	28								
	56								
	57			▨	▨	▨	▨	▨	▨
	58								
	60								
YAW ACT. ON RIGHT MTR FAIL	0	▨	▨	▨	▨	▨	▨	▨	▨
	8								
	28								
	56								
	57			▨	▨	▨	▨	▨	▨
	58								
	60								

* + = LEFT SRM "HOT", − = RIGHT SRM "HOT"

▨ INDICATES RUNS ACCOMPLISHED

FIGURE 15 RUN MATRIX 0°-90° TVC ACTUATOR SYSTEM - UNCOMPENSATED

For the headwind case, the consequent trajectory deviation resulted in a maximum dynamic pressure 10% higher than the no failure case, and $Q\beta$ increased nearly 100% but remained comfortably below the values obtained with crosswinds. The crosswind cases naturally produced the highest values of $Q\beta$ but this particular failure caused a $Q\beta$ of 11% higher than failures of other actuators. The primary reason a crosswind was selected as the design case was the high value of $Q\beta$ it produced.

The effects of thrust unbalance were slight in the mid-boost range (liftoff to about 110 seconds). Differences in the key variables typically ranged from one to three percent between high thrust on the SRM with the failed actuator and low thrust on it. But the direction of change varied from case to case, sometimes increasing and sometimes decreasing. So both directions of thrust unbalance should be checked if any significant variable is near a limiting value.

Failure time is an important consideration. The only times looked at in this set of cases were liftoff and 57 seconds, but other studies as well as this one demonstrated that, failures occurring after the start of the roll maneuver consistently produce smaller deviations in all variables (rates, errors and load indicators) than do failures during the first eight seconds of flight. Therefore, liftoff was selected as the design case failure time.

4.2.2 Thrust Tailoff Results

Pitch actuator failures did not seriously affect staging conditions for any combination of failure time, wind, or thrust unbalance studied. This was because little pitch engine deflection was required in this flight region.

Thrust unbalance produced a yaw torque during thrust tailoff lasting several seconds. If the yaw actuator failed on the SRM with thrust remaining the resulting yaw-roll disturbance became significant with respect to the staging criteria. Nominal staging time for this configuration is 123 seconds, but under these off-nominal circumstances with a crosswind, the vehicle had 17 degrees sideslip, 7.5 degrees yaw error, and -14 degrees roll error, as shown in Figures 16 through 18. As the thrust continued to decay the vehicle recovered from the unbalanced condition resulting in relatively high rates (as shown in Figures 19 and 20) of 4.8 degrees per second in roll and

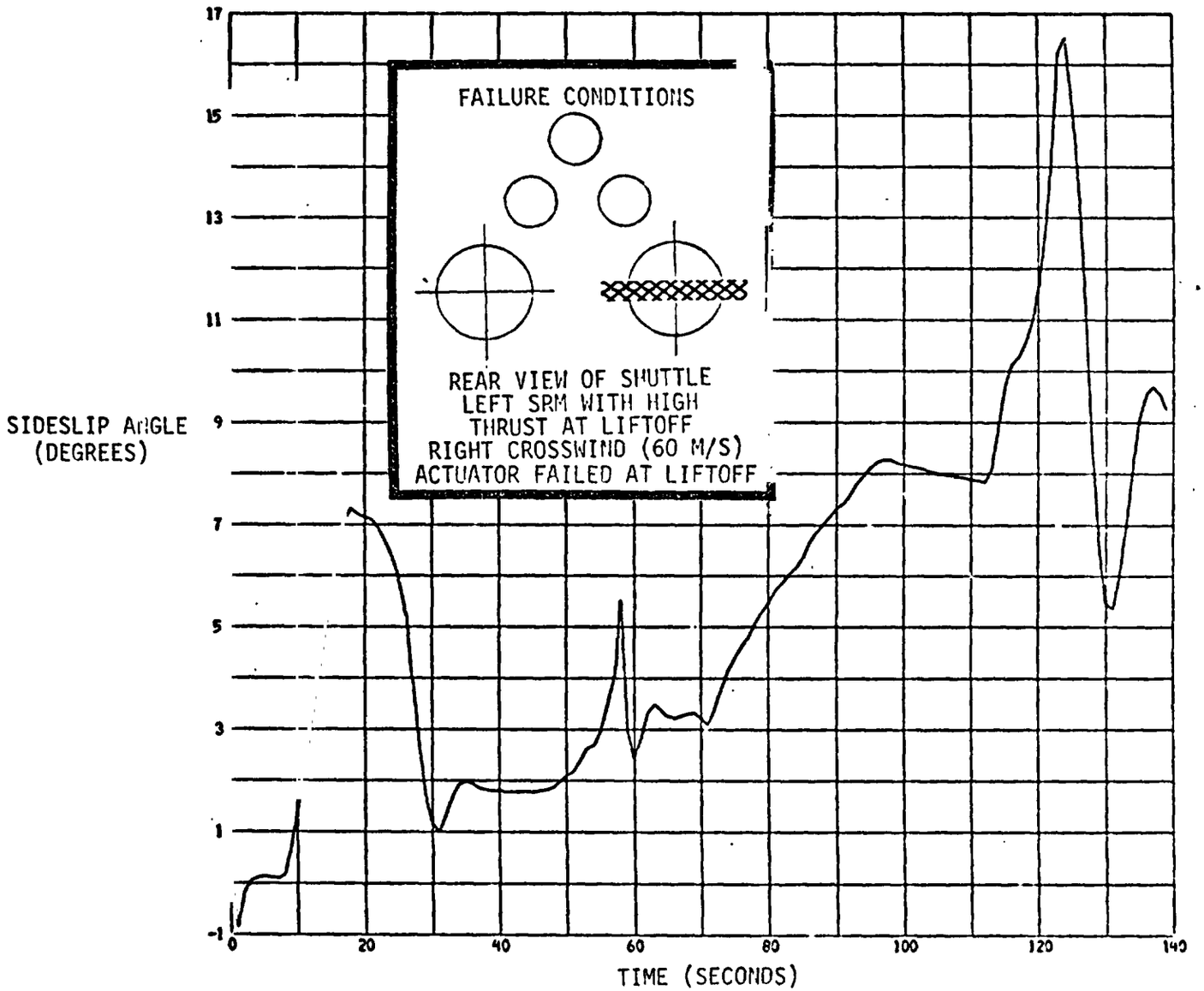


FIGURE 16 0°-90° TVC SYSTEM - UNCOMPENSATED SIDESLIP ANGLE VERSUS TIME

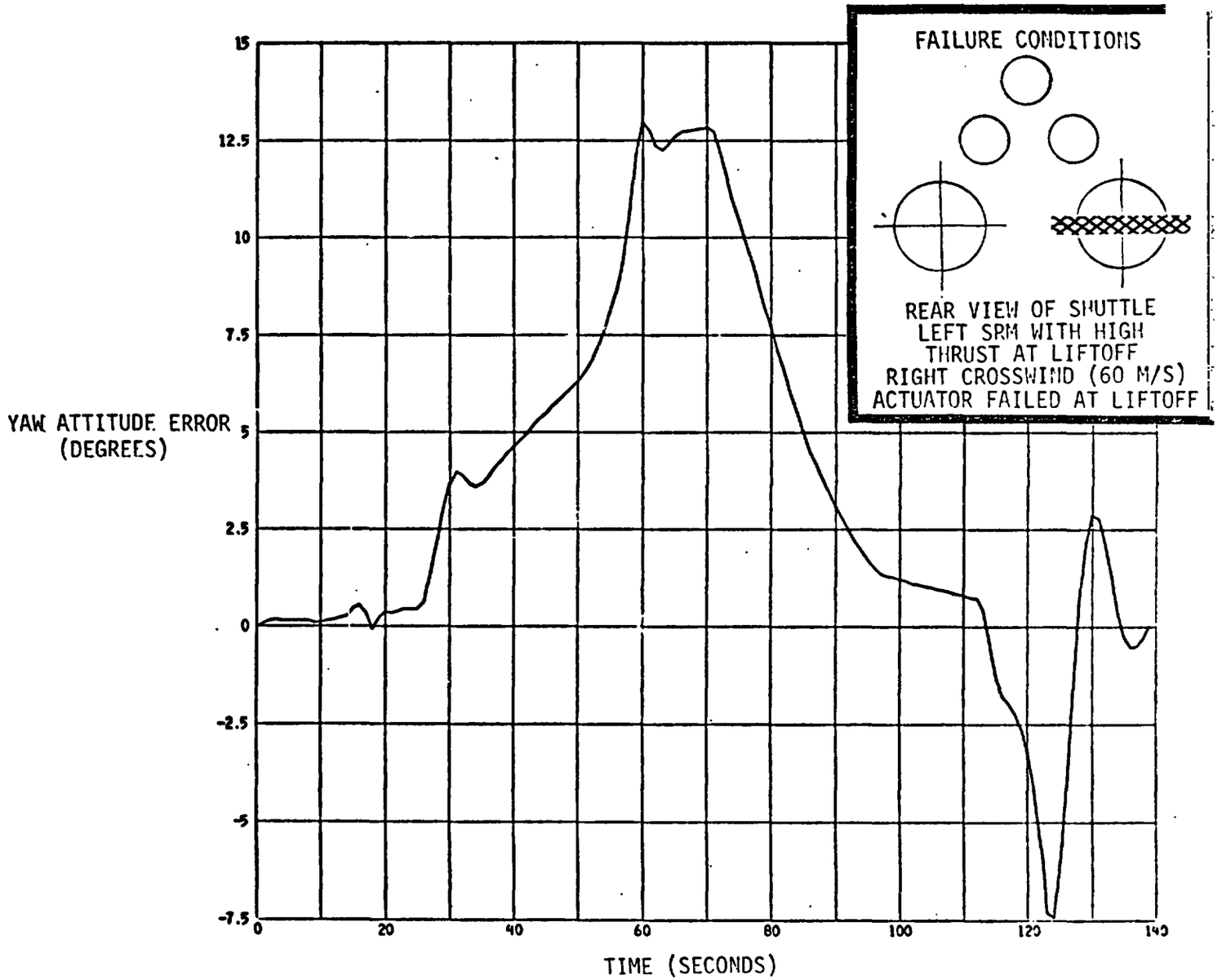


FIGURE 17 0°-90° TVC SYSTEM - UNCOMPENSATED
YAW ERROR VERSUS TIME

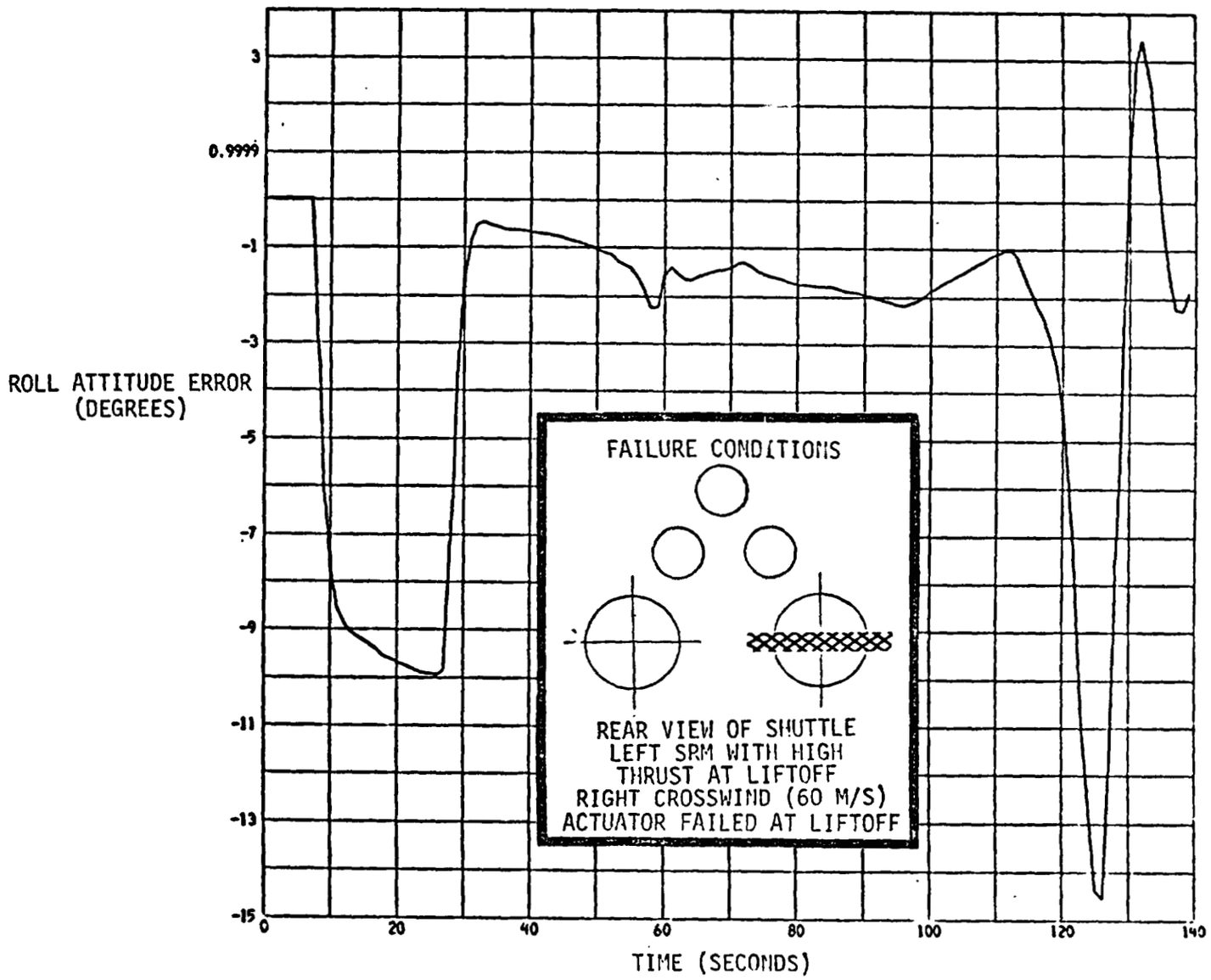


FIGURE 18 0°-90° TVC SYSTEM - UNCOMPENSATED
ROLL ERROR VERSUS TIME

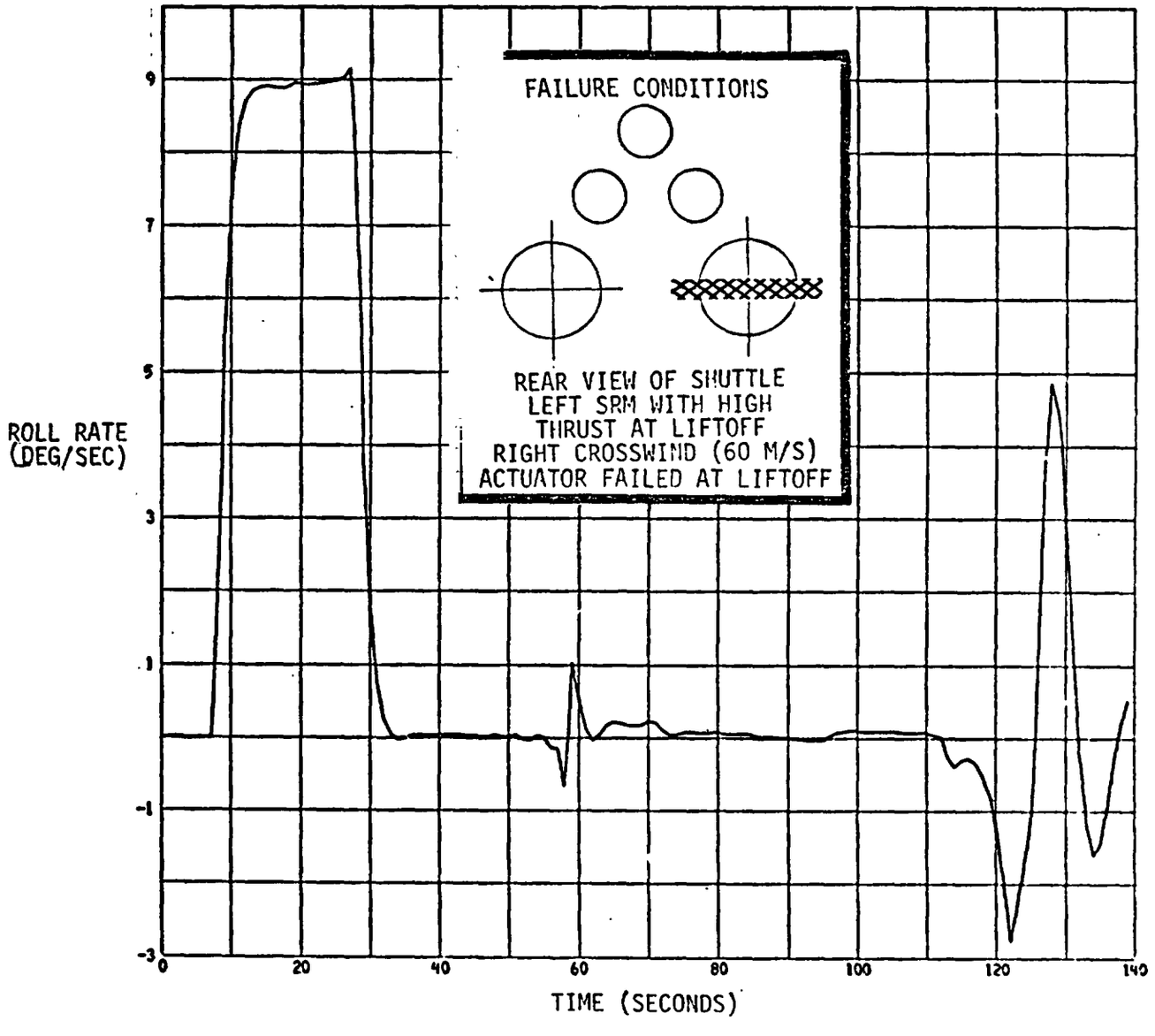


FIGURE 19 0°-90° TVC SYSTEM - UNCOMPENSATED
ROLL RATE VERSUS TIME

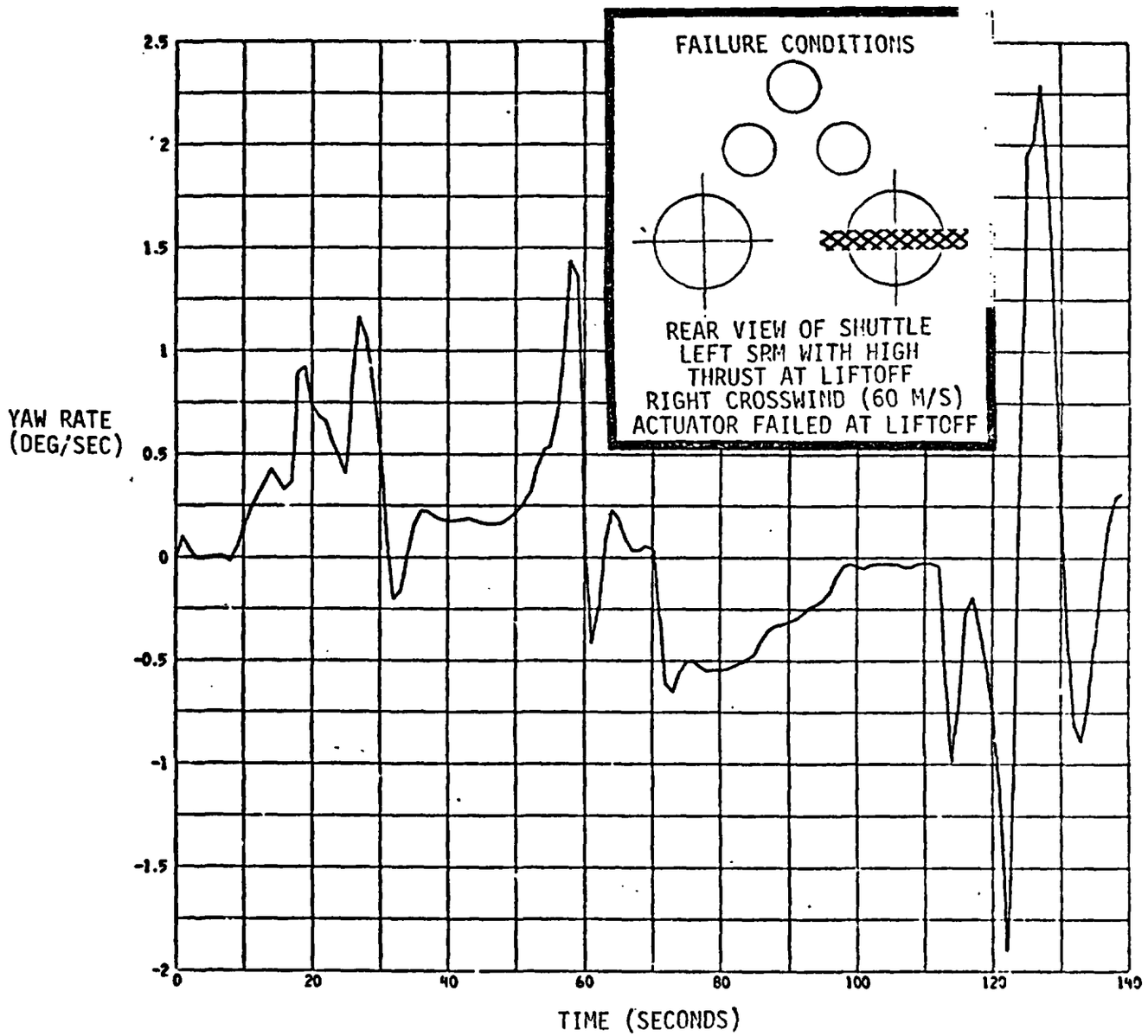


FIGURE 20 0°-90° TVC SYSTEM - UNCOMPENSATED
YAW RATE VERSUS TIME

2.3 degrees per second in yaw. However, the sideslip angle never decreased to 5 degrees and the rates were not damped out by 140 seconds.

4.2.3 Compensation Logic Discussion

Mid-boost - To compensate for a pitch actuator failure, all SRM pitch commands were transferred to the main engines (scaled up by 2.5 to account for the difference in torque between the SRM's and the SSME's). In addition, since the roll torque from the remaining SRM was unbalanced it caused a spurious pitch torque; a counteracting pitch command was issued to the main engines (scaled at 1.25). This logic is illustrated in Figure 21.

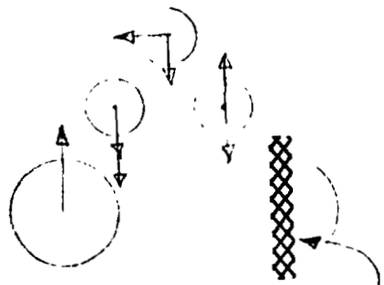
This compensation produced good results. It decreased the $Q\beta$ deviation from the original 11 percent down to 3 percent for the design case. The deviation was not reduced to zero because the SRM's are nominally biased slightly off zero pitch deflection which modifies the resultant thrust direction and trajectory.

Thrust Tailoff - Compensation at tailoff consisted primarily of reducing the roll and yaw attitude gains. From 123 to 125 seconds the roll gain was damped to zero and the yaw gain was reduced to 0.1. This decreased the attitude rates to small values similar to those an attitude hold would produce. This compensation alone created stable staging conditions, but with a crosswind the sideslip angle remained up around 12 degrees. To reduce the sideslip, the Y accelerometer was turned on (with mid-boost gain) at 124 seconds. This reduced the sideslip to 5 degrees within 6 seconds without introducing excessive rates as shown in Figures 22 through 24. Data from these studies are contained in Appendix A6.

MID-BOOST LOGIC FOR 0° - 90° ACTUATOR ORIENTATION

PITCH ACTUATOR FAILURES

ROLL COMMANDS

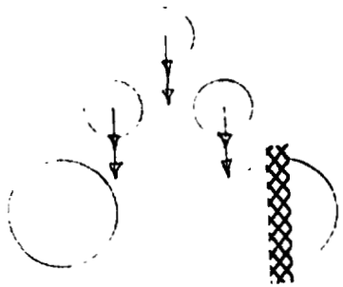


FAILED ACTUATOR

USE SSME TO COUNTERACT PITCH TORQUE FROM REMAINING SRB (SCALE FACTOR = 1.28)

LIMIT SRB ROLL COMMANDS TO 5 DEGREES

PITCH COMMANDS



YAW COMMANDS

TURN OFF PITCH TO SRB'S

ADD SRB PITCH SIGNALS TO SSME (SCALE FACTOR = 2.55)

NO CHANGE

YAW ACTUATOR FAILURES

NO CHANGE

FIGURE 21 COMPENSATION LOGIC FOR 0°-90° TVC SYSTEM

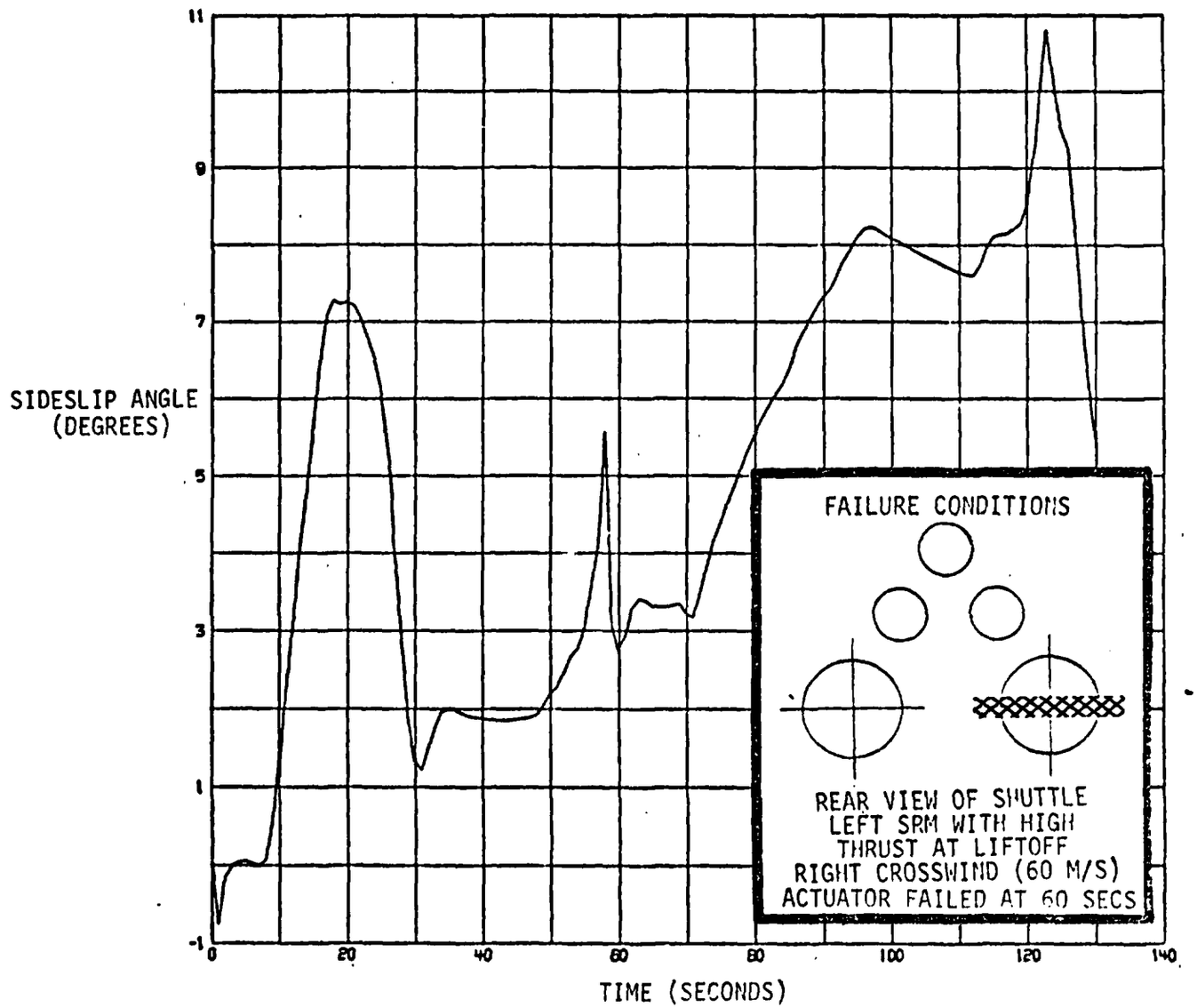


FIGURE 22 0°-90° TVC SYSTEM - COMPENSATED
SIDESLIP ANGLE VERSUS TIME

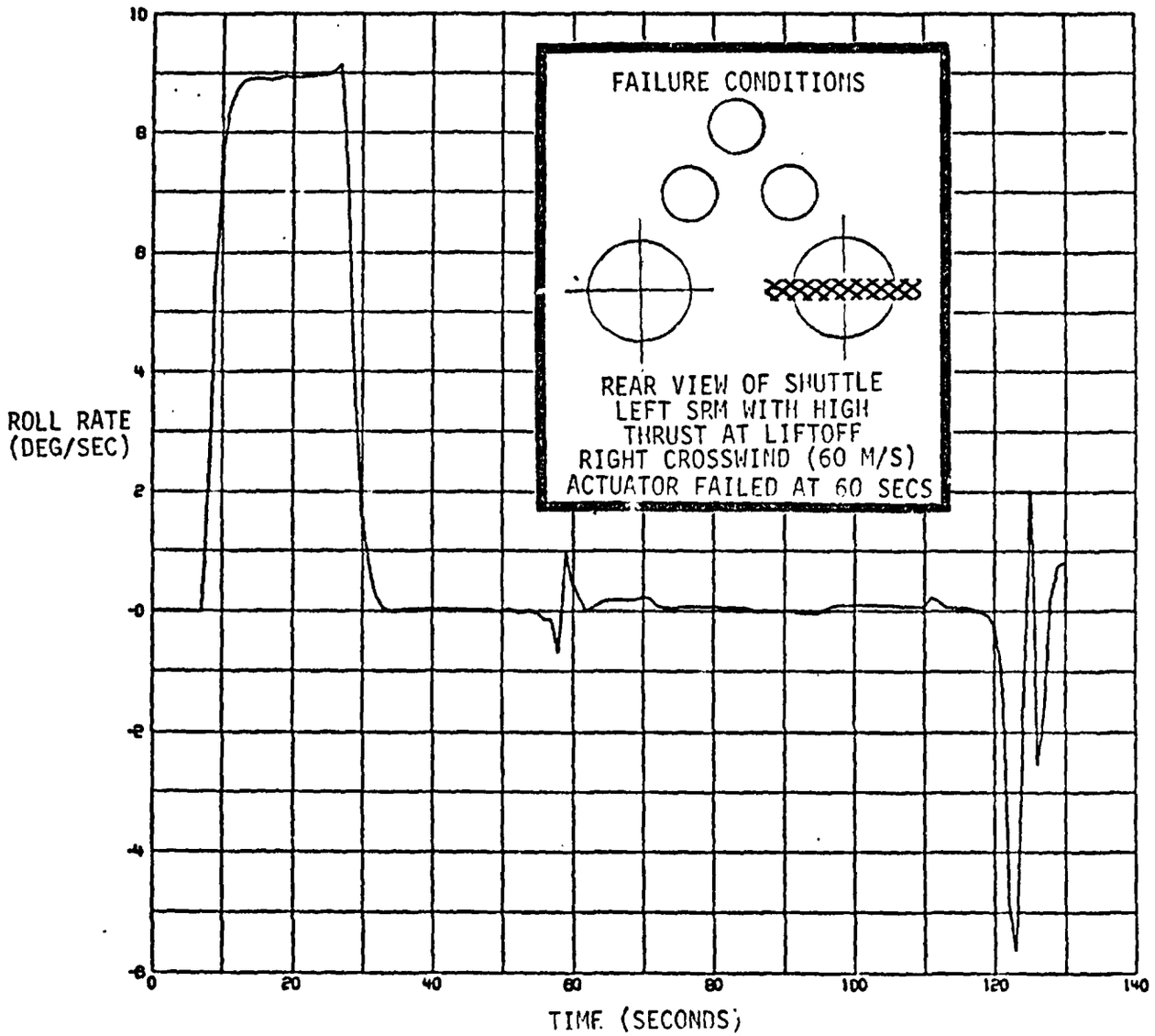


FIGURE 23 0°-90° TVC SYSTEM - COMPENSATED
ROLL RATE VERSUS TIME

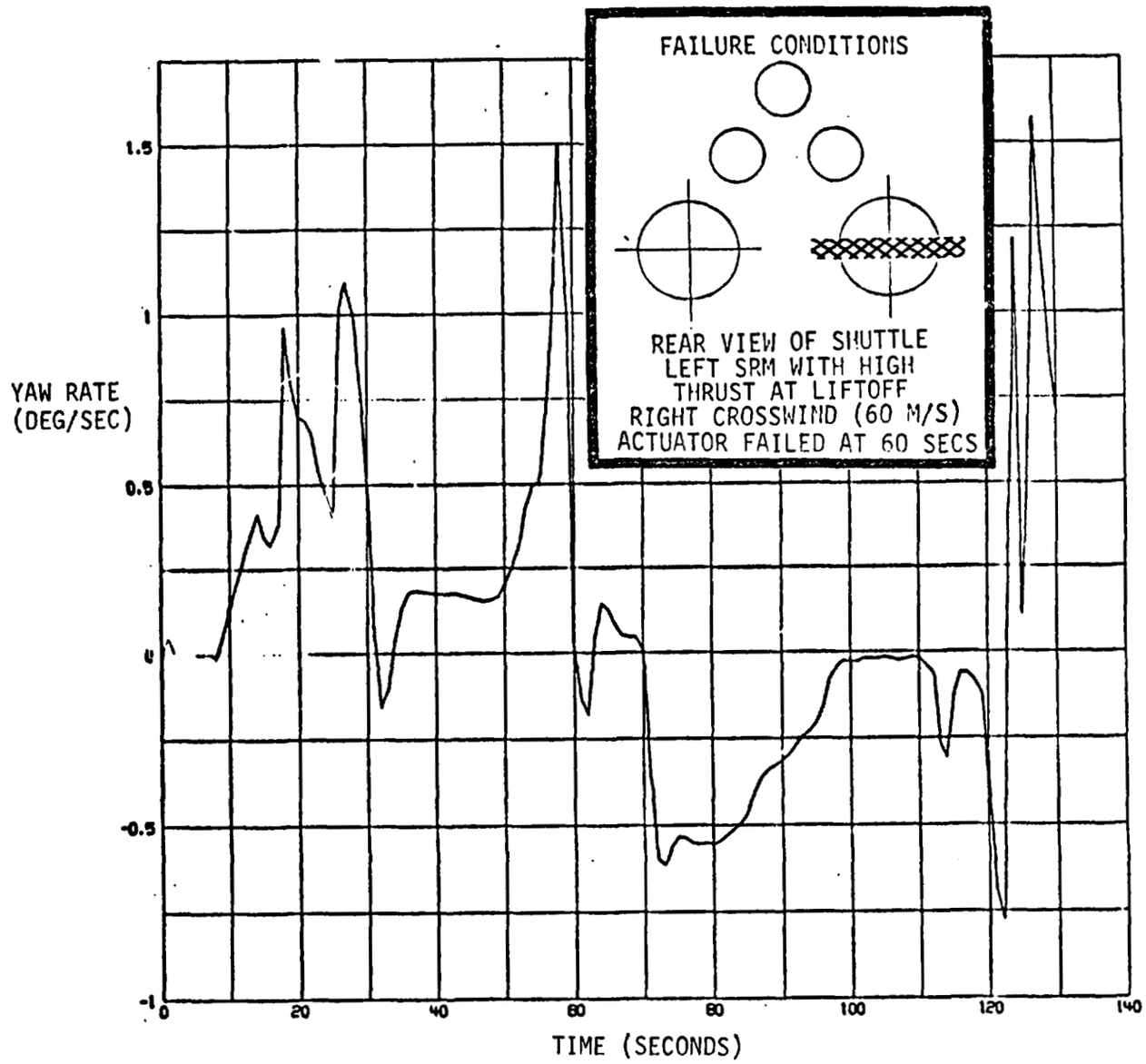


FIGURE 24 0°-90° TVC SYSTEM - UNCOMPENSATED YAW RATE VERSUS TIME

5.0 CONCLUSIONS AND RECOMMENDATIONS

During the early part of the flight, an actuator failure interfered with smooth performance of the roll maneuver. For the positive roll after liftoff used in this study, failure of the left actuator (45° - 135° configuration) or pitch actuator (0° - 90° configuration) on the right SRM resulted in significantly higher $Q\beta$ than any other failure cases. This appears to be a function of the magnitude and direction of the roll maneuver. If the roll were negative instead of positive mirror image failures would be more severe. Satisfactory compensation was developed for both configurations.

At thrust tailoff for the 45° - 135° configuration, failure of the left actuator on the right SRM or the right actuator on the left SRM, with thrust remaining on the same SRM, resulted in adverse roll-yaw torques and high body rates at staging. These adverse conditions could not be compensated for, although it was possible to do a limited amount of tradeoff between roll rates and yaw rates. Yaw actuator failures produced similar results for the 0° - 90° cases, except that the effects were not as severe and satisfactory compensation was achieved.

Because of the inability to compensate the 45° - 135° configuration and because the actuator duty cycle for the 0° - 90° configuration is only about 75 percent of the 45° - 135° duty cycle (as tabulated in the appendices), it is recommended that the 0° - 90° actuator configuration be retained as a viable alternative. It is also recommended that additional comparisons be performed to determine:

a) Effects of magnitude of roll maneuver,
b) Effects of direction of roll, and
c) Weight to orbit penalty for delaying separation until body rates are nulled.

The loads indicator $Q\beta$ was excessive for several of the cases studied. It is recommended that load relief studies be initiated.

APPENDIX A1

45° - 135° TVC BASELINE SYSTEM - UNCOMPENSATED MID-BOOST DATA

CROSSWINDS

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	0.1	703 @58	1997 @75	4042 @58	2.5 @85	12.7 @61	-11.2 @27	1.0 @62	1.5 @59	9.0 @19	
	✓	✓			✓		✓	0.1	699 @58	2071 @75	3888 @58	2.5 @85	13.0 @61	34.6 @127	-1.2 @125	-3.0 @127	9.0 @19	
✓			✓		✓		✓	0.1	710 @58	1881 @75	3913 @58	-2.1 @37	13.9 @70	-13.7 @27	1.0 @70	1.9 @59	9.1 @28	
	✓		✓		✓		✓	0.1	706 @58	1947 @75	3815 @58	-2.4 @37	14.3 @70	-13.0 @27	1.0 @70	1.9 @59	9.1 @28	
✓		✓		✓			✓	0.1	707 @58	2016 @77	3900 @58	3.0 @85	12.6 @60	-11.6 @27	1.0 @71	1.8 @59	9.0 @28	
	✓	✓		✓			✓	0.1	705 @58	2055 @77	3871 @58	2.8 @85	13.1 @70	-11.4 @27	1.0 @71	1.8 @59	9.0 @28	
✓			✓	✓			✓	0.1	697 @58	1968 @77	4521 @58	-3.1 @59	11.6 @61	-67.4 @127	-2.6 @126	2.3 @127	-12.9 @125	
	✓		✓	✓			✓	0.1	695 @58	2011 @77	4472 @58	-3.6 @59	12.1 @61	-16.9 @27	1.7 @60	1.8 @59	8.9 @12	

RUNID 150
PLOTID 55

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	8	703 @58	2007 @75	4045 @58	2.5 @85	12.8 @61	-11.1 @27	1.0 @62	1.5 @59	9.0 @19	
	✓	✓			✓		✓	8	699 @58	2074 @75	3914 @58	2.5 @85	13.1 @61	34.6 @127	-1.2 @125	-3.0 @127	9.0 @19	
✓			✓		✓		✓	8	709 @58	1892 @75	3912 @58	-2.2 @37	14.0 @70	-13.6 @27	1.0 @70	1.9 @59	9.0 @28	
	✓		✓		✓		✓	8	705 @58	1953 @75	3814 @58	-2.4 @37	14.3 @70	-12.9 @27	1.0 @70	1.9 @58	9.0 @28	
✓		✓		✓			✓	8	707 @58	2018 @77	3919 @58	3.0 @85	12.6 @60	-11.6 @27	1.0 @71	1.8 @59	9.0 @28	
	✓	✓		✓			✓	8	704 @58	2060 @77	3848 @58	2.8 @85	13.1 @70	-11.3 @27	1.0 @71	1.8 @59	9.0 @28	
✓			✓	✓			✓	8	data lost									
	✓		✓	✓			✓	8	data lost									

RUNID 154
PLOTID 546

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	28	702 @58	2022 @75	4049 @58	2.5 @85	12.9 @61	-10.0 @25	1.0 @62	1.5 @59	9.1 @27	
	✓	✓			✓		✓	28	700 @58	2084 @75	3958 @58	2.4 @85	13.2 @61	34.4 @127	-1.2 @125	3.0 @127	9.2 @27	
✓			✓		✓		✓	28	701 @58	1920 @75	3815 @58	-2.4 @37	13.3 @70	-10.0 @25	1.0 @70	1.9 @58	9.1 @27	
	✓		✓		✓		✓	28	699 @58	1972 @75	3757 @58	-2.6 @37	13.8 @70	-10.0 @26	1.0 @70	1.9 @58	9.2 @27	
✓		✓		✓			✓	28	704 @58	2052 @77	3968 @58	2.9 @85	12.6 @70	-10.0 @25	1.0 @71	1.8 @59	9.1 @27	
	✓	✓		✓			✓	28	701 @58	2084 @77	3807 @58	2.7 @85	13.1 @70	-10.0 @26	1.0 @71	1.8 @58	9.2 @27	
✓			✓	✓			✓	28	695 @58	1949 @77	4421 @58	-2.9 @59	11.2 @61	-66.8 @127	-2.5 @126	2.4 @127	-12.7 @125	
	✓		✓	✓			✓	28	691 @58	1984 @77	4392 @58	-3.3 @59	11.5 @61	-10.0 @26	1.6 @60	1.8 @58	9.2 @27	

RUNID 155
PLOTID 304

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	58	702 @58	1998 @75	3996 @58	2.5 @85	12.7 @61	-10.0 @25	1.0 @62	1.6 @58	9.1 @27	
	✓	✓			✓		✓	58	700 @58	2067 @75	3826 @58	2.5 @85	13.1 @60	34.6 @127	-1.2 @125	-3.0 @127	9.2 @27	
✓			✓		✓		✓	58	702 @58	1856 @75	3996 @58	-2.2 @36	12.9 @60	-10.0 @25	1.1 @61	1.9 @59	9.1 @27	
	✓		✓		✓		✓	58	700 @58	1911 @75	3826 @58	-2.4 @37	13.3 @60	-10.0 @26	1.0 @61	1.9 @59	9.2 @27	
✓		✓		✓			✓	58	702 @58	2062 @77	3996 @58	2.8 @85	12.5 @60	-10.0 @25	1.1 @59	1.9 @59	9.1 @27	
	✓	✓		✓			✓	58	700 @58	2090 @77	3826 @58	2.6 @85	13.0 @70	-10.0 @26	1.0 @59	1.8 @58	9.2 @27	
✓			✓	✓			✓	58	702 @58	1910 @77	3996 @58	-2.2 @36	11.9 @60	-68.6 @127	-2.6 @126	2.3 @127	-13.1 @125	
	✓		✓	✓			✓	58	700 @58	1940 @77	3826 @58	-2.4 @37	12.4 @60	-10.0 @26	1.0 @71	1.6 @58	9.2 @27	

RUNID 171
PLOTID 75

NO WIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	0.1	656 @57	1869 @78	1437 @24	2.4 @85	-4.7 @123	-10.4 @27	1.0 @70	1.2 @125	9.2 @27	
	✓	✓			✓		✓	0.1	652 @56	1943 @78	1459 @25	-2.4 @37	10.3 @124	46.0 @127	-1.8 @126	-2.9 @127	9.1 @28	
✓			✓		✓		✓	0.1	660 @58	1803 @77	1473 @25	2.2 @84	-4.6 @123	-12.7 @27	1.0 @70	1.2 @124	9.3 @28	
	✓		✓		✓		✓	0.1	655 @57	1870 @77	1479 @25	-2.3 @37	5.0 @70	-11.9 @27	1.0 @70	1.1 @27	9.3 @28	
✓		✓		✓			✓	0.1	659 @58	1865 @77	1362 @24	2.8 @85	-4.0 @123	-10.8 @26	1.0 @70	1.1 @27	9.2 @27	
	✓	✓		✓			✓	0.1	656 @57	1901 @78	1439 @25	2.5 @85	5.1 @123	-10.6 @26	1.0 @70	-1.2 @125	9.2 @27	
✓			✓	✓			✓	0.1	654 @56	1880 @78	1543 @25	-2.3 @36	-9.8 @124	-53.6 @127	-2.1 @126	2.7 @127	-10.2 @125	
	✓		✓	✓			✓	0.1	651 @54	1910 @78	1690 @25	-2.6 @36	5.0 @123	-15.8 @27	1.0 @71	1.4 @29	9.2 @28	

RUNID 159
PLOTID 209

ETR TAILWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	0.1	595 @5.0	3620 @58	1356 @85	-11.5 @59	5.6 @60	-9.3 @27	1.5 @72	1.2 @125	9.1 @13	
	✓	✓			✓		✓	0.1	593 @50	3661 @58	1377 @86	-11.8 @59	10.9 @124	40.9 @127	-1.6 @126	-3.1 @127	9.1 @12	
✓			✓		✓		✓	0.1	594 @50	3644 @58	1150 @85	-11.7 @59	-4.6 @123	-9.5 @25	1.5 @72	1.2 @124	9.1 @26	
	✓		✓		✓		✓	0.1	592 @49	3679 @58	1190 @86	-12.0 @59	5.2 @70	-9.5 @26	1.6 @72	1.0 @27	9.1 @18	
✓		✓		✓			✓	0.1	594 @50	3685 @58	938 @81	-11.3 @59	-4.1 @123	-9.3 @27	1.6 @71	1.0 @27	9.0 @26	
	✓	✓		✓			✓	0.1	592 @50	3704 @58	999 @83	-11.7 @59	5.0 @123	-9.3 @27	1.6 @71	-1.2 @125	9.0 @26	
✓			✓	✓			✓	0.1	593 @49	3621 @58	1139 @48	-12.0 @59	-10.5 @124	-46.5 @127	-1.8 @126	2.9 @127	9.2 @27	
	✓		✓	✓			✓	0.1	591 @49	3681 @58	1229 @49	-12.5 @59	5.0 @123	-10.0 @27	1.6 @71	-1.2 @125	9.2 @27	

RUNID 162
PLOTID 155

VAFB HEADWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	0.1	753 @58	-1929 @33	2024 @23	4.1 @59	-4.7 @123	-15.3 @27	2.1 @59	1.3 @29	9.2 @28	
	✓	✓			✓		✓	0.1	747 @58	-1863 @33	2023 @24	3.8 @59	9.9 @124	48.1 @127	2.1 @58	-2.7 @127	9.3 @125	
✓			✓		✓		✓	0.1	764 @58	-2122 @34	2158 @24	4.5 @60	4.9 @70	-20.9 @27	2.1 @59	1.2 @124	9.4 @29	
	✓		✓		✓		✓	0.1	757 @58	-2000 @34	2118 @24	4.1 @59	5.2 @70	-19.2 @27	2.1 @59	1.2 @27	9.4 @29	
✓		✓		✓			✓	0.1	761 @58	-1967 @34	1940 @23	4.6 @59	-4.0 @123	-16.3 @27	2.1 @59	1.2 @27	9.3 @29	
	✓	✓		✓			✓	0.1	755 @58	-1892 @33	1978 @23	4.2 @59	5.1 @123	-15.4 @27	2.1 @59	-1.3 @125	9.3 @28	
✓			✓	✓			✓	0.1	752 @58	-2042 @35	2221 @24	3.9 @60	-9.2 @124	-57.6 @127	-2.2 @126	2.5 @127	-11.2 @125	
	✓		✓	✓			✓	0.1	748 @58	-2012 @35	2357 @25	3.6 @59	5.3 @32	-24.7 @27	2.1 @59	1.6 @30	9.4 @30	

RUNID 164
PLOTTD 163

AR

VAFB HWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL. (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	28	750 @58	-1843 @33	1947 @23	3.9 @59	-4.7 @123	-11.5 @26	2.1 @59	1.2 @125	9.4 @28	
	✓	✓			✓		✓	28	746 @58	-1774 @33	1956 @23	3.7 @59	10.0 @124	4.8 @127	2.2 @58	-2.8 @127	9.4 @28	
✓			✓		✓		✓	28	749 @58	-1879 @33	1947 @23	3.8 @59	-4.6 @123	-11.5 @26	2.1 @58	1.2 @124	9.4 @28	
	✓		✓		✓		✓	28	745 @58	-1810 @33	1956 @23	3.6 @59	4.4 @70	-11.5 @26	2.2 @58	1.2 @124	9.4 @28	
✓		✓		✓			✓	28	752 @58	-1840 @33	1947 @23	4.2 @59	-4.0 @123	-11.5 @26	2.1 @59	1.1 @27	9.4 @28	
	✓	✓		✓			✓	28	747 @58	-1784 @33	1956 @23	3.9 @59	5.1 @123	-11.6 @26	2.1 @58	-1.3 @125	9.4 @28	
✓			✓	✓			✓	28	749 @58	-1941 @34	1947 @23	3.8 @59	-9.4 @124	-56.1 @127	2.1 @59	2.5 @127	-10.9 @125	
	✓		✓	✓			✓	28	744 @58	-1878 @34	1956 @23	3.5 @59	5.0 @123	-11.5 @26	2.2 @58	-1.2 @125	9.4 @28	

RUNID 174
PLOTID 81

APPENDIX A2

45° - 135° TVC BASELINE SYSTEM - UNCOMPENSATED STAGING CONDITION DATA

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
									DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS STAGE TIME
L	R	L	R	L	R	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓		✓	0.1	20	52	59	-7.4	8.5 (8)	0	.9	1.9	4.3	>(140)
	✓	✓			✓		✓	0.1	24	57	58	-11.1	-1.7 (8)	-.7	-3.0	-2.4	4.3	>(140)
✓			✓		✓		✓	0.1	47	29	56	-6.6	10.0 (9)	0.1	0.1	1.5	4.3	>(140)
	✓		✓		✓		✓	0.1	48	28	54	-7.7	7.2 (10)	0	-0.8	-1.0	4.3	>(140)
✓		✓		✓			✓	0.1	25	48	63	-7.5	9.9 (7.6)	-0.1	0.7	1.4	4.4	>(140)
	✓	✓		✓			✓	0.1	27	47	72	-8.0	4.9	-0.8	-1.2	0.4	4.4	125
✓			✓	✓			✓	0.1	60	29	54	3.0	12.2 (7.6)	-1.7	2.3	-5.6	4.3	>(140)
	✓		✓	✓			✓	0.1	59	29	62	-7.4	4.6	-0.5	-1.3	-0.4	4.3	125

RUNID 156
PLOTID 55

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
									DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS STAGE TIME
L	R	L	R	L	R	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓		✓	8	21	50	59	-7.4	8.5 (8.0)	0	0.9	1.9	4.3	>(140)
	✓	✓			✓		✓	8	24	56	57	-11.1	-1.7 (8.0)	-0.7	-3.0	-2.4	4.3	>(140)
✓			✓		✓		✓	8	47	31	55	-6.6	10.1 (9.4)	0.1	0.8	1.5	4.3	>(140)
	✓		✓		✓		✓	8	48	29	54	-7.7	7.2 (10.1)	0	-0.8	-1.0	4.3	>(140)
✓		✓		✓			✓	8	26	48	63	-7.5	9.9 (9.6)	-0.1	0.7	1.4	4.4	>(140)
	✓	✓		✓			✓	8	(27)	(47)	(72)	(-7.9)	(4.9)	(-0.7)	(-1.2)	(0.4)	(4.4)	(125)
✓			✓	✓			✓	8	data lost									
	✓		✓	✓			✓	8	data lost									

RUNID 154

PLOTID 246

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
									DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS STAGE TIME
L	R	L	R	L	R	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓		✓	28	23	48	58	-7.3	8.6 (8.0)	0.0	0.9	1.9	4.3	>(140)
	✓	✓			✓		✓	28	27	53	58	-11.1	-1.6 (8.1)	-0.7	-3.0	-2.4	4.3	>(140)
✓			✓		✓		✓	28	44	32	53	-6.5	9.8 (9.1)	0.1	0.8	1.5	4.3	>(140)
	✓		✓		✓		✓	28	45	31	53	-7.6	7.0 (9.8)	0.0	-0.8	-1.0	4.3	>(140)
✓		✓		✓			✓	28	29	47	62	-7.4	9.9 (9.5)	-0.1	0.7	1.4	4.4	>(140)
	✓	✓		✓			✓	28	(30)	(46)	(70)	(-7.9)	(4.9)	-0.7	-1.2	-0.4	4.4	(125)
✓			✓	✓			✓	28	54	31	54	2.7	12.1 (8.4)	-1.7	2.3	-5.5	4.3	>(140)
	✓		✓	✓			✓	28	(52)	(30)	(61)	(-1.4)	(4.3)	(-0.5)	(-1.1)	(-0.4)	4.3	(125)

RUNID 155

PLOTID 304

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
L	R	L	R	L	R	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS STAGE TIME
✓		✓			✓		✓	58	26	46	59	-7.4	8.4 (8.0)	0.0	0.9	1.9	4.3	>(140)
	✓	✓			✓		✓	58	30	51	59	-11.1	-1.7 (8.0)	-0.7	-3.0	-2.4	4.3	>(140)
✓			✓		✓		✓	58	44	38	55	-6.7	9.4 (8.8)	0.1	0.8	1.5	4.3	>(140)
	✓		✓		✓		✓	58	46	37	54	-7.7	6.7 (9.5)	0.0	-0.8	-1.0	4.3	>(140)
✓		✓		✓			✓	58	32	47	61	-7.3	9.9 (9.5)	-0.1	0.8	1.4	4.4	>(140)
	✓	✓		✓			✓	58	(33)	(47)	(70)	(-7.8)	(4.9)	(-0.7)	(-1.2)	(0.4)	(4.4)	(125)
✓			✓	✓			✓	58	47	35	56	3.1	12.2 (8.5)	-1.8	2.2	-5.8	4.3	>(140)
	✓		✓	✓			✓	58	(44)	(34)	(64)	(-7.6)	(4.5)	(-0.4)	(-1.1)	(-0.4)	(4.3)	(125)

RUNID 171
PLOTID 75

A14

NO WIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
L	R	L	R	L	R	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS STAGE TIME
✓		✓			✓		✓	0.1	(18)	(39)	(63)	(-6.8)	(4.8)	(-0.5)	(1.1)	(0.6)	(4.3)	(125.0)
	✓	✓			✓		✓	0.1	19	44	52	-7.2	-7.1 (-7.7)	-1.2	-2.8	.42	4.3	(128.2)
✓			✓		✓		✓	0.1	(38)	(24)	(61)	(-6.7)	(5.0)	(-0.6)	(0.9)	(0.1)	(4.3)	(125.3)
	✓		✓		✓		✓	0.1	(37)	(22)	(61)	(-6.8)	(-5.1)	(-0.3)	(-0.8)	(0.7)	(4.3)	(125.0)
✓		✓		✓			✓	0.1	(21)	(37)	(65)	(-6.9)	(4.9)	(-0.4)	(0.8)	(6.0)	(4.3)	(125.1)
	✓	✓		✓			✓	0.1	(22)	(37)	(64)	(-7.1)	(-0.9)	(-0.7)	(-1.1)	(0.2)	(4.3)	(125.0)
✓			✓	✓			✓	0.1	42	21	52	-3.9	9.7 (5.0)	-1.4	2.6	-2.2	4.3	(129.3)
	✓		✓	✓			✓	0.1	(41)	(21)	(60)	(-6.9)	(-1.0)	(-0.5)	(-1.1)	-0.5	(4.3)	(125.0)

RUNID 159
PLOTID 209

A15

ETR TAILWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
L	R	L	R	L	R	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS STAGE TIME
✓		✓			✓		✓	0.1	(21)	(45)	(39)	(-3.5)	(5.0)	(-0.5)	(1.0)	(0.6)	(4.0)	(125.2)
	✓	✓			✓		✓	0.1	(27)	(50)	(28)	(-6.1)	(0.9)	(0.5)	(-2.0)	(-9.7)	(4.0)	(128.7)
✓			✓		✓		✓	0.1	(43)	(26)	(39)	(-3.1)	(4.9)	(-0.7)	(1.0)	(-0.1)	(4.0)	(125.1)
	✓		✓		✓		✓	0.1	(41)	(25)	(38)	(-3.3)	(0.1)	(-0.4)	(-0.8)	(0.1)	(4.0)	(125.0)
✓		✓		✓			✓	0.1	(24)	(42)	(40)	(-3.4)	(4.6)	(-0.5)	(0.8)	(-0.1)	(4.0)	(125.0)
	✓	✓		✓			✓	0.1	(25)	(45)	(39)	(-3.6)	(-0.4)	(-0.8)	(-1.1)	(0.2)	(4.0)	(125.0)
✓			✓	✓			✓	0.1	(47)	(23)	(28)	(-3.7)	(3.1)	(0.4)	(2.0)	(8.6)	(4.0)	(128.5)
	✓		✓	✓			✓	0.1	(43)	(24)	(37)	(-3.3)	(-1.2)	(-0.6)	(-1.1)	(-0.4)	(4.0)	(125.0)

RUNID 162
PLØTID 155

VAFB HEADWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
L	R	L	R	L	R	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS STAGE TIME
✓		✓			✓		✓	0.1	(21)	(46)	(76)	(-8.0)	(4.7)	(-0.5)	(1.1)	(0.7)	(4.5)	(125.0)
	✓	✓			✓		✓	0.1	22	50	64	-7.8	-8.1 (-5.0)	-1.2	-2.7	0.7	4.5	(128.2)
✓			✓		✓		✓	0.1	(45)	(27)	(75)	(-8.2)	(4.9)	(-0.4)	(0.8)	(0.4)	(4.5)	(125.6)
	✓		✓		✓		✓	0.1	(45)	(25)	(76)	(-8.1)	(-0.6)	(-0.3)	(-0.8)	(0.0)	(4.5)	(125.0)
✓		✓		✓			✓	0.1	(25)	(44)	(79)	(-8.3)	(4.9)	(-0.4)	(0.7)	(0.1)	(4.5)	(125.3)
	✓	✓		✓			✓	0.1	(25)	(43)	(78)	(-8.4)	(-1.1)	(-0.7)	(-1.2)	(0.1)	(4.5)	(125.0)
✓			✓	✓			✓	0.1	52	25	64	-4.0	10.7 (3.5)	-1.4	-2.4	-2.9	4.5	(132.3)
	✓		✓	✓			✓	0.1	(49)	(23)	(74)	(-8.3)	(-0.9)	(-0.5)	(-1.1)	(-0.6)	(4.5)	(125.0)

RUNID 164

PLOTID 163

VAFB HWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
L	R	L	R	L	R	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS STAGE TIME
✓		✓			✓		✓	28	(24)	(41)	(75)	(-8.0)	(4.8)	(-0.5)	(1.1)	(0.7)	(4.5)	(125.0)
	✓	✓			✓		✓	28	25	44	63	-7.9	-7.9 (-4.8)	-1.2	-2.7	0.6	4.5	(128.2)
✓			✓		✓		✓	28	(40)	(29)	(72)	(-7.7)	(4.9)	(-0.6)	(1.1)	(0.1)	(4.4)	(125.1)
	✓		✓		✓		✓	28	(40)	(28)	(71)	(-7.9)	(-1.0)	(-0.3)	(-0.8)	(0.0)	(4.4)	(125.0)
✓		✓		✓			✓	28	(27)	(41)	(75)	(-8.1)	(5.0)	(-0.3)	(0.7)	(0.1)	(4.5)	(125.3)
	✓	✓		✓			✓	28	(28)	(40)	(75)	(-8.2)	(-1.1)	(-0.7)	(-1.2)	(0.1)	(4.5)	(125.0)
✓			✓	✓			✓	28	45	27	63	-4.4	10.4 (3.0)	-1.4	2.4	-2.6 (9.9)	4.5	(132.1)
	✓		✓	✓			✓	28	(41)	(25)	(72)	(-8.2)	(-1.4)	(-0.5)	(-1.1)	(-0.6)	(4.4)	(125.0)

RUNID 174
PLOTID 81

A18

APPENDIX A3

45° - 135° TVC BASELINE SYSTEM - COMPENSATED MID-BOOST DATA AND STAGING CONDITION DATA

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		8	700 @58	2000 @77	4059 @58	5.8 @112	12.7 @60	-11.2 @27	-1.3 @116	1.7 @58	9.1 @28	
	✓	✓			✓	✓		8	698 @58	2050 @78	3972 @58	5.9 @112	14.0 @126	14.0 @126	-2.2 @115	3.9 @123	9.0 @28	
✓			✓		✓	✓		8	700 @58	1993 @77	4072 @58	5.8 @112	12.4 @70	-11.3 @27	-1.2 @116	1.7 @58	9.1 @28	
	✓		✓		✓	✓		8	698 @58	2042 @78	3892 @58	5.8 @112	13.0 @70	-11.4 @27	-1.7 @115	1.7 @58	9.0 @28	
✓		✓		✓		✓		8	700 @58	2000 @77	4054 @58	5.8 @112	12.4 @70	-11.2 @27	-1.7 @115	1.8 @58	9.1 @28	
	✓	✓		✓		✓		8	698 @58	2050 @78	3961 @58	5.7 @112	13.0 @70	-11.4 @27	-1.3 @116	1.8 @58	9.0 @28	
✓			✓	✓		✓		8	700 @58	1997 @77	4063 @58	5.8 @112	-14.5 @127	-22.9 @127	-2.2 @115	-3.8 @122	9.1 @28	
	✓		✓	✓		✓		8	698 @58	2044 @78	3920 @58	5.6 @112	13.2 @60	-11.5 @27	-1.3 @116	1.8 @58	9.1 @28	

RUNID 158
PLØTID 31

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		0.1	701 (57.9)	1992 (77.3)	4068 (57.9)	5.8 (112.4)	12.7 (60.0)	-11.3 (27.0)	-1.3 (116.2)	1.7 (58.4)	9.1 (27.6)	
	✓	✓			✓	✓		0.1	699 (57.9)	2041 (77.4)	3903 (57.9)	5.9 (112.3)	14.0 (126.2)	14.0 (126.4)	-2.2 (114.8)	3.9 (122.6)	9.1 (27.7)	
✓			✓		✓	✓		0.1	700 (57.9)	1988 (77.4)	4082 (57.9)	5.8 (112.4)	12.4 (69.9)	-11.3 (27.0)	-1.2 (116.2)	1.7 (58.3)	9.1 (27.6)	
	✓		✓		✓	✓		0.1	699 (57.9)	2037 (77.5)	3902 (57.9)	5.9 (112.3)	13.0 (69.9)	-11.5 (27.0)	-1.7 (114.1)	1.7 (58.3)	9.1 (27.7)	
✓		✓		✓		✓		0.1	701 (57.9)	1992 (77.3)	4069 (57.9)	5.8 (112.3)	12.5 (69.9)	-11.3 (27.0)	-1.7 (114.8)	1.8 (58.4)	9.1 (27.6)	
	✓	✓		✓		✓		0.1	699 (57.9)	2042 (77.5)	3907 (57.9)	5.7 (112.4)	13.0 (69.9)	-11.5 (27.0)	-1.3 (116.2)	1.8 (58.4)	9.1 (27.7)	
✓			✓	✓		✓		0.1	701 (57.9)	1992 (77.3)	4065 (57.9)	5.8 (112.3)	-14.5 (126.5)	-23.2 (127.0)	-2.2 (114.8)	-3.8 (122.4)	9.1 (27.6)	
	✓		✓	✓		✓		0.1	699 (57.9)	2040 (77.5)	3921 (57.9)	5.6 (112.4)	13.2 (60.0)	-11.6 (27.0)	-1.3 (116.3)	1.8 (58.4	9.1 (27.7)	

RUNID -146
PLØTID 165

YAW ATTITUDE GAIN OFF FROM 1 0-125

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	L	R	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		57	702 @58	1958 @77	4000 @58	5.9 @112	12.5 @60	-10.0 @25	-1.3 @116	1.6 @59	9.1 @27	
	✓	✓			✓	✓		57	700 @58	2004 @77	3847 @58	5.9 @112	20.8 @127	10.2 @125	-2.2 @115	4.0 @123	9.2 @27	
✓			✓		✓	✓		57	702 @58	1958 @77	3902 @58	5.9 @112	13.3 @60	-10.0 @25	1.4 @61	2.3 @59	9.1 @27	
	✓		✓		✓	✓		57	700 @58	2005 @77	3742 @58	5.9 @112	13.8 @60	-10.0 @26	-1.7 @115	2.3 @59	9.2 @27	
✓		✓		✓		✓		57	702 @58	1956 @77	3951 @58	5.9 @112	12.6 @60	-10.0 @25	-1.7 @115	1.9 @59	9.1 @27	
	✓	✓		✓		✓		57	700 @58	2005 @77	3198 @58	5.7 @112	13.0 @60	-10.0 @26	-1.3 @116	1.9 @58	9.1 @27	
✓			✓	✓		✓		57	702 @58	4068 @70	4132 @58	5.9 @112	-21.4 @127	-22.3 @71	2.9 @69	-3.9 @123	-11.9 @69	
	✓		✓	✓		✓		57	700 @58	2199 @63	3969 @58	5.7 @112	13.8 @61	-10.0 @26	2.0 @66	-1.7 @62	9.2 @27	

RUNID 170
PLOTID 12

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
									DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS STAGE TIME
L	R	L	R	L	R	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓	✓		8	32	67	59	-7.5	11.6 (8.3)	-0.1	-0.3	-0.4	4.4	>(140)
	✓	✓			✓	✓		8	33	69	57	-9.5	-6.3 (10.0)	-0.3	-1.5	-1.0	4.3	>(140)
✓			✓		✓	✓		8	64	33	59	-7.5	11.0 (8.1)	-0.3	-0.5	-0.8	4.4	>(140)
	✓		✓		✓	✓		8	65	33	57	-8.1	5.5 (10.0)	-0.1	0.7	1.0	4.3	>(140)
✓		✓		✓		✓		8	32	66	58	-7.4	11.2 (8.1)	-0.1	-0.7	-0.9	4.3	>(140)
	✓	✓		✓		✓		8	31	63	58	-8.1	5.7 (10.0)	-0.2	0.5	0.8	4.3	>(140)
✓			✓	✓		✓		8	72	34	58	-3.9	24.1 (5.0)	-0.7	0.7	0.1	4.3	(133.6)
	✓		✓	✓		✓		8	78	35	58	-8.3	5.1 (9.9)	-0.1	0.3	0.5	4.3	>(140)

RUNID 158
PLOTID 31

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.2 SEC)									
L	R	L	R	L	R	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS
✓		✓			✓	✓		0.1	32	68	58	-7.6	11.7	-.1	-.2	-.3	4.4	
	✓	✓			✓	✓		0.1	31	66	56	-9.6	-6.0	-.3	-1.8	-1.3	4.3	
✓			✓		✓	✓		0.1	60	31	58	-7.7	11.1	-.3	-.4	-.7	4.4	
	✓		✓		✓	✓		0.1	62	31	57	-8.2	5.4	-.1	.5	-.8	4.3	
✓		✓		✓		✓		0.1	31	63	58	-7.5	11.3	-.1	-.6	-.8	4.3	
	✓	✓		✓		✓		0.1	31	63	57	-8.3	5.6	-.2	.4	.7	4.4	
✓			✓	✓		✓		0.1	67	31	57	-4.1	24.1	-.7	.9	.6	4.3	
	✓		✓	✓		✓		0.1	72	32	57	-8.5	5.1	-.1	.2	.4	4.4	

RUNID -146
PLØTID 165

YAW ATTITUDE OFF FROM 120-125

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
L	R	L	R	L	R	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS STAGE TIME
✓		✓			✓	✓		57	37	59	60	-7.8	12.9 (16.6)	-0.1	-1.2	-0.2	4.4	>(140)
	✓	✓			✓	✓		57	38	60	58	-9.8	-13.1 (-14.8)	0.0	2.4	-0.9	4.3	>(140)
✓			✓		✓	✓		57	68	44	60	-7.8	11.9 (15.9)	0.0	-1.2	-0.5	4.4	>(140)
	✓		✓		✓	✓		57	(71)	(44)	(59)	(-8.0)	(4.9)	-0.1	1.3	0.7	4.4	(126.8)
✓		✓		✓		✓		57	39	66	60	-7.7	12.1 (16.3)	-0.1	-1.3	-0.5	4.4	>(140)
	✓	✓		✓		✓		57	(38)	(62)	(60)	(-8.0)	(5.0)	(-0.3)	(1.2)	(0.8)	4.4	(126.7)
✓			✓	✓		✓		57	137	64	60	-8.0	30.2 (34.2)	-0.1	-2.5	1.1	4.3	>(140)
	✓		✓	✓		✓		57	(94)	(47)	(63)	(-8.0)	(4.9)	-0.1	1.4	0.9	4.4	(126.0)

RUNID 170
PLOTTED 72

APPENDIX A4

0° - 90° TVC SYSTEM - UNCOMPENSATED MID-BOOST DATA

No WIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)										
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS	β MAX
✓		✓			✓		✓	0.1	661 (58)	1855 (78)	1495 (25)	+3.4 (108)	-4.2 (123)	-16.7 (27)	-1.0 (12)	+1.2 (27)	+9.3 (12)	-1.5 (122)	+7.9 (18)
	✓	✓			✓				657 (57)	1904 (78)	1524 (25)	+3.3 (108)	+4.7 (123)	-16.5 (27)	+1.0 (70)	+1.2 (27)	+9.3 (12)	-.4 [illegible]	-7.6 (18)
✓			✓		✓				665 (58)	1709 (78)	2053 (25)	+2.6 (112)	+5.5 (70)	-34.5 (27)	-1.3 (9)	+1.2 (30)	+9.2 (31)	-2.1 (122)	+8.6 (18)
	✓		✓		✓				661 (57)	1756 (78)	2062 (26)	+2.6 (112)	+6.1 (70)	-34.9 (27)	-1.2 (9)	+1.3 (30)	+9.2 (31)	-1.1 (116)	+8.2 (20)
✓		✓		✓					658 (58)	1858 (77)	1363 (24)	+2.5 (83)	-4.5 (123)	-9.8 (25)	+1.0 (70)	+1.1 (124)	+9.2 (27)	-1. (122)	+7.5 (18)
	✓	✓		✓					654 (57)	1913 (77)	1427 (25)	-2.4 (37)	+10.2 (124)	+14.1 (126)	-1.0 (125)	-3.2 (127)	+9.2 (27)	-3.3 (127)	+7.2 (18)
✓			✓	✓					658 (58)	1859 (77)	1364 (24)	+2.5 (83)	-9.0 (124)	-14.1 (126)	+1.0 (70)	+2.8 (127)	+9.2 (27)	-2.8 (122)	+11.7 (124)
	✓		✓	✓					654 (57)	1913 (77)	1427 [illegible]	-2.4 (37)	-4.9 (123)	-9.9 (26)	+1.0 (70)	+1.1 (27)	+9.2 (27)	-.2 (34)	-1.2 (18)

No WIND (L/O)

RUNID -163

PLØTID 479

HEADWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	0.1	767 (58)	-2258 (33)	2142 (24)	+4.9 (60)	-4.1 (123)	-28.7 (27)	+2.1 (59)	+1.3 (27)	+9.2 (30)	
	✓	✓			✓				761 (58)	-2199 (33)	2135 (24)	+4.6 (60)	+4.6 (123)	-28.0 (27)	+2.1 (59)	+1.4 (27)	+9.2 (30)	
✓			✓		✓				818 (60)	-2107 (37)	3741 (89)	+5.7 (72)	+10.1 (70)	-70.6 (28)	+2.0 (60)	+2.0 (30)	+7.7 (12)	
	✓		✓		✓				811 (59)	-2011 (37)	3780 (89)	+5.3 (72)	+10.5 (70)	-69.9 (28)	+2.0 (59)	+2.0 (30)	+7.8 (33)	
✓		✓		✓					754 (58)	-1878 (35)	1919 (23)	+4.2 (59)	-4.4 (123)	-10.9 (26)	+2.1 (59)	+1.1 (27)	+9.4 (27)	
	✓	✓		✓					748 (58)	-1792 (34)	1949 (23)	+3.9 (59)	+10.0 (124)	+14.4 (126)	+2.2 (58)	-3.1 (127)	+9.4 (28)	
✓			✓	✓					754 (58)	-1871 (35)	1920 (23)	+4.2 (59)	-8.7 (124)	-14.4 (126)	+2.1 (59)	+2.7 (127)	+9.4 (27)	
	✓		✓	✓					748 (58)	-1792 (34)	1949 (23)	+3.9 (59)	+4.9 123	-11.3 (26)	+2.2 (58)	+1.2 (27)	+9.4 (28)	

HEADWIND (i/o)

RUNID -172

PLOTID —

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
							✓	0.1	594 (49)	3540 (58)	1200 (83)	-12.1 (59)	+4.9 (60)	-9.5 (27)	+1.6 (72)	+1.0 (26)	+9.7 (12)	
									593 (49)	3555 (58)	1250 (84)	-12.4 (59)	+5.6 (60)	-9.6 (27)	+1.6 (72)	+1.0 (122)	+9.7 (12)	
									592 (49)	3472 (58)	1137 (47)	-13.5 (60)	-4.6 (123)	-11.0 (27)	+1.6 (72)	-1.0 (122)	+9.6 (13)	
									590 (49)	3508 (58)	1184 (48)	-13.8 (59)	+4.4 (123)	-11.6 (27)	+1.6 (72)	-1.0 (124)	+9.6 (13)	
									595 (50)	3744 (58)	1024 (83)	-10.9 (59)	-4.6 (123)	-9.3 (27)	+1.5 (72)	+1.1 (125)	+9.0 (27)	
									593 (50)	3774 (58)	1072 (84)	-11.3 (59)	+10.5 (124)	+13.7 (126)	+1.5 (72)	-3.3 (127)	+9.0 (27)	
									595 (50)	3744 (58)	1025 (83)	-10.9 (59)	-9.5 (124)	-13.7 (126)	+1.5 (72)	+3.0 (127)	+9.0 (27)	
									593 (50)	3774 (58)	1072 (84)	-11.3 (59)	+4.9 (123)	-9.4 (27)	+1.5 (72)	-1.1 (125)	+9.0 (27)	

TAILWIND (L/O)

RUNID -177

PLOTID 350

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)										
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS BINV
✓		✓			✓		✓	0.1	709 (58)	2064 (78)	3990 (58)	+4.4 (99)	12.0 (70)	-17.7 (27)	+1.2 (62)	+1.7 (58)	+9.3 (12) -1.5 (122)	+11.5 (123)
	✓	✓			✓				706 (58)	2117 (78)	3822 (58)	+4.5 (99)	+12.6 (70)	-17.6 (27)	+1.1 (62)	+1.7 (58)	+9.4 (12) -.2 (58)	+8.8 (98)
✓			✓		✓				717 (58)	1917 (62)	4479 (58)	-8.5 (60)	+15.0 (70)	-35.9 (27)	+1.8 (61)	+2.1 (59)	+8.9 (13) -5.6 (59)	+14.2 (127)
	✓		✓		✓				715 (58)	1975 (62)	4295 (58)	-8.8 (60)	+15.6 (70)	-36.3 (27)	+1.7 (61)	+2.1 (59)	+8.9 (13) -5.9 (59)	+11.1 (97)
✓		✓		✓					705 (58)	1952 (75)	3991 (58)	+2.4 (84)	+13.0 (60)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.2 (27) -1.7 (122)	+12.8 (123)
	✓	✓		✓					702 (58)	2010 (75)	3856 (58)	-2.4 (37)	+13.3 (60)	+12.8 (125)	-1.1 (125)	+2.8 (122)	+9.2 (27) -.6 (58)	+8.6 (97)
✓			✓	✓					705 (58)	1952 (75)	3973 (58)	+2.4 (84)	+12.9 (60)	-14.7 (126)	+1.0 (70)	+2.3 (127)	+9.2 (27) -2.8 (122)	+16.5 (124)
	✓		✓	✓					702 (58)	2010 (75)	3856 (58)	-2.4 (37)	+13.3 (60)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.2 (27) -.6 (58)	+8.6 (97)

CROSSWIND (L/R)

RUNID -157

PLOTID 97

HEADWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	57	752 (58)	-1849 (35)	1947 (23)	+4.1 (79)	-4.2 (123)	-11.5 (26)	+2.0 (59)	+1.1 (27)	+9.4 (28)	
	✓	✓			✓				747 (58)	-1782 (34)	1956 (23)	+3.9 (79)	+4.6 (123)	-11.5 (26)	+2.0 (59)	+1.2 (27)	+9.4 (28)	
✓			✓		✓				752 (58)	-1849 (35)	+1947 (23)	+3.6 (72)	-4.4 (123)	-11.5 (26)	+1.7 (59)	+1.1 (27)	+9.4 (28)	
	✓		✓		✓				747 (58)	-1782 (34)	+1956 (23)	+3.3 (72)	+4.5 (123)	-11.5 (26)	+1.7 (59)	+1.2 (27)	+9.4 (28)	
✓		✓		✓					752 (58)	-1849 (35)	+1947 (23)	+4.1 (59)	-4.5 (123)	-11.5 (26)	+2.1 (58)	+1.1 (27)	+9.4 (28)	
	✓	✓		✓					747 (58)	-1782 (34)	+1956 (23)	+3.9 (59)	+10.0 (124)	+14.4 (126)	+2.2 (58)	-3.1 (127)	+9.4 (28)	
✓			✓	✓					752 (58)	-1849 (35)	+1947 (23)	+4.1 (59)	-8.8 (124)	-14.4 (126)	+2.1 (58)	+2.7 (127)	+9.4 (28)	
	✓		✓	✓					747 (58)	-1782 (34)	+1956 (23)	+3.9 (59)	+4.9 (123)	-11.5 (26)	+2.2 (58)	+1.2 (27)	+9.4 (28)	

HEAD WIND (57)
RUNID -169
PLOTID (627)

TAIL WIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓		✓	57	595 (50)	3672 (58)	1027 (83)	-12.0 (59)	+4.3 (60)	-9.3 (27)	+1.8 (61)	+1.0 (26)	+9.0 (27)	-1.5 (122)
	✓	✓			✓				593 (50)	3692 (58)	1078 (85)	-12.2 (59)	+5.0 (60)	-9.3 (27)	+1.8 (61)	+1.0 (122)	+9.0 (27)	-.4 (1)
✓			✓		✓				595 (50)	3674 (58)	984 (62)	-12.8 (60)	-4.6 (123)	-9.3 (27)	+1.8 (61)	-1.0 (122)	+9.0 (27)	-2.0 (122)
	✓		✓		✓				593 (50)	3696 (58)	987 (83)	-13.1 (60)	+4.4 (123)	-9.3 (27)	+1.9 (61)	+1.0 (26)	+9.0 (27)	-1.7 (57)
✓		✓		✓					595 (50)	3745 (58)	972 (83)	-10.9 (59)	-4.6 (123)	-9.3 (27)	+1.5 (72)	+1.1 (125)	+9.0 (27)	-1.5 (22)
	✓	✓		✓					593 (50)	3768 (58)	1032 (84)	-11.2 (59)	+10.4 (124)	+13.7 (126)	+1.5 (72)	-3.3 (127)	+9.0 (27)	-2.8 (27)
✓			✓	✓					595 (50)	3745 (58)	973 (83)	-10.9 (57)	-9.5 (124)	-13.7 (126)	+1.5 (72)	+3.0 (127)	+9.0 (27)	-2.7 (122)
	✓		✓	✓					593 (50)	3768 (58)	1031 (84)	-11.2 (57)	+4.9 (123)	-9.3 (27)	+1.5 (72)	-1.1 (125)	+9.0 (27)	-.1 (71)

TAILWIND (57)
RUNID -167
PLOTID 840

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)										
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS BMAX
✓		✓			✓		✓	57	702 (58)	2158 (78)	3996 (58)	+4.2 (104)	+12.3 (70)	-10.0 (25)	+1.2 (62)	+1.7 (58)	+9.1 (27)	-1.0 (122) 11.8 (123)
	✓	✓			✓				700 (58)	2205 (78)	3834 (58)	+4.2 (99)	+12.9 (70)	-10.0 (26)	+1.1 (62)	+1.7 (58)	+9.2 (27)	-1.0 (58) +9.1 (97)
✓			✓		✓				702 (58)	1759 (78)	4018 (58)	-5.0 (60)	+12.1 (70)	-10.0 125	+1.8 (61)	+1.7 (59)	+9.1 (27)	-4.0 (59) +12.7 (123)
	✓		✓		✓				700 (58)	1796 (77)	3849 (58)	-5.1 (60)	+12.6 (70)	-10.0 (26)	+1.8 (61)	+1.7 (58)	+9.2 (27)	-3.8 (59) +5.6 (97)
✓		✓		✓					702 (58)	1959 (75)	3945 (58)	+2.4 (84)	+12.8 (60)	-10.0 (25)	+1.0 (70)	+1.8 (59)	+9.1 (27)	-1.7 (122) +12.6 (123)
	✓	✓		✓					700 (58)	2007 (75)	3810 (58)	-2.4 (37)	+13.1 (60)	+12.8 (125)	-1.1 (125)	+2.8 (122)	+9.2 (27)	-.6 (59) +9.4 (97)
✓			✓	✓					702 (58)	1960 (75)	3947 (58)	+2.4 (84)	+12.7 (60)	-14.7 (126)	-1.0 (125)	+2.3 (127)	+9.1 (27)	-2.0 (122) +1.5 (124)
	✓		✓	✓					700 (58)	2007 (75)	3809 (58)	-2.4 (37)	+13.1 (60)	-10.0 (26)	+1.0 (70)	+1.7 (59)	+9.2 (27)	-.6 (58) +5.4 (97)

CROSSWIND (57)

RUNID 165
PLØTID 121

APPENDIX A5

0° - 90° TVC SYSTEM - UNCOMPENSATED STAGING CONDITION DATA

No WIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
									DCYCLE		Q	α	β	θ̇	ψ̇	φ̇	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		STAGING TIME
✓		✓			✓		✓	0.1	(17)	(38)	(70)	(-7.8)	(+4.6)	(-.6)	(+.8)	(+.2)	(4.4)	(125.0)
	✓	✓			✓				(17)	(38)	(68)	(-8.3)	(-2.1)	(-.2)	(-.9)	(-.1)	(4.3)	(125.0)
✓			✓		✓				39	18	55	-7.5	+5.0	-.09	+1.0	+1.8	4.3	127.0
	✓		✓		✓				(39)	(17)	(63)	(-7.3)	(+.2)	(-.5)	(-.8)	(-.05)	(4.3)	(125.0)
✓		✓		✓					(17)	(37)	(62)	(-6.5)	(+5.0)	(-.4)	(+.9)	(+.2)	(4.3)	(125.2)
	✓	✓		✓					21	39	52	-8.1	-2.4 (+3.6)	-.1 (+.4)	-3.2 (-1.9)	-3.3 (-5.6)	4.3	(128.8)
✓			✓	✓					38	23	53	-7.4	+5.8 (+1.2)	-.09 (+.3)	+2.8 (+1.9)	+3.5 +5.3	4.3	(128.5)
	✓		✓	✓					(35)	(18)	(61)	(-6.8)	-1.1	(-.5)	(-1.0)	(-.02)	4.3	(125.0)

No WIND L/O

RUNID -163

PLØTID 479

HEADWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
									DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		STAGING TIME
✓		✓			✓		✓	0.1	(17)	42	(+89)	(-9.2)	(+4.6)	(-.6)	(+.9)	(+.3)	(4.5)	(125.0)
	✓	✓			✓				(18)	43	(86)	(-9.7)	(-2.5)	(-.2)	(-.9)	(-.1)	(4.5)	(125.0)
✓			✓		✓				47	18	89	-9.0 (-9.7)	+7.0 (+5.0)	+.04 (-.04)	+1.0 (+.9)	+2.1 (+2.6)	4.5	(128.5)
	✓		✓		✓				(45)	(18)	(99)	(-9.3)	(+1.8)	(-.5)	(-.9)	(-.1)	(4.5)	(125.0)
✓		✓		✓					(20)	(40)	(73)	(-7.7)	(+5.0)	(-.4)	(+.9)	(+.3)	(4.5)	(125.3)
	✓	✓		✓					25	43	(62)	-9.2 (-9.1)	-2.5 (+3.3)	-.1 (+.4)	-3.1 (-1.9)	-3.6 (-5.7)	4.4	(128.7)
✓			✓	✓					42	25	64	-8.5 (-8.9)	+5.6 (+1.6)	-.07 (+.3)	+2.7 (+2.0)	+3.7 (+5.3)	4.5	(128.3)
	✓		✓	✓					(39)	(21)	(72)	(-7.9)	(-1.3)	(-.4)	(-1.0)	(-.06)	(4.4)	(125.0)

HEADWIND L/O

RUNID -172

PLATTD —

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
L	R	L	R	Y	P.	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS STAGING TIME
✓		✓			✓		✓	0.1	17	41	41	-3.	+4.9	-.6	+.8	+.01	4.0	125.0
	✓	✓			✓				18	40	40	-4.6	-.9	-.2	-.9	-.1	4.0	125.0
✓			✓		✓				40	18	36	-3.1	+5.0	-.1	+.9	+.2	3.9	125.1
	✓		✓		✓				41	17	35	-2.9	-3.3	-.6	-.8	+.06	3.9	125.0
✓		✓		✓					20	41	40	-3.2	+5.0	-.5	+1.0	-.01	4.0	125.0
	✓	✓		✓					25	42	33	-4.9 (-4.3)	-2.0 (+4.3)	-.07 (+.5)	-3.3 (-1.9)	-2.8 (-5.5)	4.0	(129.0)
✓			✓	✓					41	26	34	-4.1 (-4.2)	+5.8 (+.8)	-.03 (+.5)	+3.0 (+2.0)	+3.0 (+5.3)	4.0	(128.7)
	✓		✓	✓					40	21	39	-3.5	-.5	-.5	-1.0	+.04	4.0	125.0

TAILWIND (4/0)
RUNID 177
PLØTID 350

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
									DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		STAGING TIME
✓		✓			✓		✓	0.1	20	47	71	-9	+8.6 (+8.4)	-.02 (-.02)	+.8 (-.07)	+1.6 (-.1)	4.4	>140
	✓	✓			✓				(21)	(46)	(81)	(-10)	[illegible]	(-.2)	(-.8)	(+.1)	(4.4)	(125
✓			✓		✓				52	22	52	-5.7	+11.3 (+10.1)	+.1 (-.01)	+1.0 (+.1)	+2.0 (+.3)	4.3	>(140)
	✓		✓		✓				52	22	51	-7.6	+[illegible].0 (+10.8)	+.0 (-.01)	-.8 (-.1)	+1.2 (-.2)	4.3	>(140)
✓		✓		✓					21	49	57	-6.7	+9.8 (+9.1)	+.01 (-.01)	+.8 (-.2)	+1.6 (+.8	4.3	>(140)
	✓	✓		✓					(24)	(48)	(66)	(-7.9)	(-3.3)	(-1.1)	(-1.6)	(+2.0	(4.3)	(125.0)
✓			✓	✓					48	28	57	-6.2	+10.9 (+8.8)	+.003 (-.01)	+2.3 (-.09)	+[illegible] (+1.3)	4.3	>(140)
	✓		✓	✓					(44)	(23)	(66)	(-7.5)	(+4.7)	(-.4)	(-1.1)	(+.1)	(4.3	(125.0

CROSSWIND (40)

RUNID -57

PLOTID 97

HEADWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
L	R	L	R	Y	P.	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS STAGING TIME
✓		✓			✓		✓	57	(-4)	(38)	(82)	(-8.9)	(+4.8)	(-.6)	(+.9)	(+.3)	(4.5)	(125.0)
	✓	✓			✓				(25)	(3.8)	(80)	(-9.4)	(-2.2)	(-.2)	(-.9)	(-.1)	(4.5)	(125.0)
✓			✓		✓				(38)	(27)	(71)	(-8.7)	(+5.0)	(+.09)	(+.6)	(+.7)	(4.5)	(125.9)
	✓		✓		✓				(37)	(27)	(74)	(-8.5)	(-1.2)	(-.5)	(-.9)	(-.1)	(4.5)	(125.0)
✓		✓		✓					(26)	(38)	(72)	(-7.7)	(+5.0)	(-.4)	(+.9)	(+.2)	(4.5)	(125.2)
	✓	✓		✓					29	40	(62)	-9.2	-2.6 (+3.2)	-.1 (+.4)	-3.1 (-1.9)	-3.6 (-5.7)	4.4	(128.7)
✓			✓	✓					40	30	(63)	-8.4 (-8.5)	+5.6 (+1.6)	-.07 (+.3)	+2.7 (+2.0)	+3.7 (+5.3)	4.5	(128.3)
	✓		✓	✓					(36)	(26)	(72)	(-7.9)	(-1.3)	(-.4)	(-1.0)	(-.06)	4.4	(125.0)

HEADWIND (57)
RUNID -169
PLATID (...)

TAIL WIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
									DCYCLE		Q	α	β	θ̇	ψ̇	φ̇	M	COMMENTS STAGING TIME
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓		✓	57	(27)	(41)	(42)	(-4.2)	(+4.5)	(-.6)	(+.8)	(+.09)	(4.0)	(125.0)
	✓	✓			✓				(28)	(40)	(41)	(-4.8)	(-1.3)	(-.2)	(-.9)	(-.1)	(4.0)	(125.0)
✓			✓		✓				(40)	(30)	(38)	(-3.8)	(+4.9)	(-.1)	(+.8)	(+.3)	(4.0)	(125.2)
	✓		✓		✓				(41)	(30)	(38)	(-3.6)	(-.5)	(-.6)	(-.8)	(+.05)	(4.0)	(125.0)
✓		✓		✓					(24)	(39)	(40)	(-3.2)	(+4.8)	(-.5)	(+1.0)	(-.01)	(4.0)	(125.0)
	✓	✓		✓					30	40	33	-4.9	-2.1 (+4.2)	-.06 (-.5)	-3.3 (-1.9)	-2.8 (-5.5)	4.0	(127.0)
✓			✓	✓					39	31	34	-4.1	+5.7 (+.7)	-.03 (+.5)	+3.0 (+2.0)	+3.0 (+5.3)	4.0	(128.7)
	✓		✓	✓					(37)	(26)	(39)	(-3.5)	(-.6)	(-.5)	(-1.0)	(+.04)	(4.0)	(125.0)

TAILWIND (57)
RUNID 167
PLOTTD 8/10

A40

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.2 SEC)									
									DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		STAGING TIME
✓		✓			✓		✓	57	26	42	67	-8.7	+8.8 (+8.5)	-.02 (-.02)	+.8 (-.1)	+1.6 (-.1)	4.4	>(140)
	✓	✓			✓				(27)	(42)	(77)	(-9.5)	(+3.3)	(-.2)	(-.9)	(+.1)	(4.4)	(125.0)
✓			✓		✓				43	33	53	-6.3	+9.8 (+8.6)	+.2 (-.01)	+1.0 (+.1)	+2.0 (+.3)	4.3	>(140)
	✓		✓		✓				(42)	(33)	(61)	(-7.3)	(+4.9)	(-.5)	(-.8)	(+.06)	(4.3)	(125.0)
✓		✓		✓					26	46	57	-6.6	+9.7 (+8.9)	+.2 (-.01)	+.8 (+.14)	+1.6 (+.7)	4.3	>(140)
	✓	✓		✓					(29)	(46)	(65)	(-7.8)	(-3.4)	(-1.1)	(-1.7)	(+2.0)	(4.3)	(125.0)
✓			✓	✓					46	33	56	-6.1	+10.9 (+8.7)	+.005 (-.01)	+2.3 (-.01)	+3.8 (+1.2)	4.3	>(140)
	✓		✓	✓					(41)	(28)	(63)	(-7.4)	(+4.6)	(-.4)	(-1.1)	(+.1)	(4.3)	(125.0)

CROSS WIND (5)

RUNID -165

PLOTTED 121

A41

APPENDIX A6

0° - 90° TVC SYSTEM - COMPENSATED MID-BOOST DATA AND STAGING CONDITION DATA

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		0.1	703 @58	1938 @75	4012 @58	8.0 @112	11.7 @60	-9.8 @26	-1.7 @116	1.6 @59	9.1 @27	
	✓	✓			✓	✓		0.1	700 @58	1983 @75	3934 @58	8.0 @112	12.2 @70	-9.8 @26	-1.7 @115	1.6 @59	9.1 @27	
✓			✓		✓	✓		0.1	696 @58	1847 @75	4145 @58	3.8 @112	12.4 @60	-9.9 @26	-1.3 @116	1.6 @59	9.1 @27	
	✓		✓		✓	✓		0.1	694 @58	1896 @76	3994 @58	3.7 @112	13.0 @70	-9.9 @26	-1.3 @116	1.6 @59	9.1 @27	
✓		✓		✓		✓		0.1	702 @58	1960 @75	3997 @58	2.4 @84	12.3 @70	-10.0 @26	1.0 @70	1.7 @58	9.1 @27	
	✓	✓		✓		✓		0.1	700 @58	2007 @75	3825 @58	-2.4 @36	12.9 @70	-10.0 @26	1.0 @70	1.7 @58	9.2 @27	
✓			✓	✓		✓		0.1	702 @58	1961 @75	3998 @58	2.3 @84	12.3 @70	-10.0 @26	1.0 @70	1.7 @58	9.1 @27	
	✓		✓	✓		✓		0.1	700 @58	2007 @75	3825 @58	-2.4 @37	12.9 @70	-10.0 @26	1.0 @70	1.7 @58	9.2 @27	

CROSSWIND 4/0

RUNID -143
PLOTID 152

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		8	702 (58)	+1944 (75)	+4087 (58)	+8.0 (112)	+11.7 (60)	-9.8 (26)	-1.6 (116)	+1.6 (58)	+9.1 (27) -1.[illegible] (1[illegible])	[illegible] (12[illegible])
	✓	✓			✓				700 (58)	1988 (75)	3909 (58)	+8.0 (112)	+12.2 (70)	-9.8 (26)	-1.7 (115)	+1.6 (58)	+9.1 (27) -1.8 (124)	8.1 (97)
✓			✓		✓				696 (58)	1846 (75)	4130 (58)	+3.8 (112)	+12.4 (60)	-9.9 (26)	-1.4 (9)	+1.7 (59)	+9.3 (10) -2.8 (122)	8.6 (123)
	✓		✓		✓				694 (58)	[illegible] (75)	4072 (58)	+3.7 (112)	+12.9 (70)	-9.9 (26)	-1.4 (9)	+1.6 (59)	+9.2 (10) -1.5 (124)	8.6 (97)
✓		✓		✓					702 (58)	1960 (75)	3997 (58)	+2.3 (84)	+12.3 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.1 (27) -2.3 (126)	8.5 (126)
	✓	✓		✓					700 (58)	2007 (75)	3826 (58)	-2.4 (36)	+12.9 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.1 (27) -3.6 (125)	8.6 (97)
✓			✓	✓					702 (58)	1961 (75)	3998 (58)	+2.3 (84)	+12.3 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.1 (27) -3.9 (122)	9.7 (123)
	✓		✓	✓					700 (58)	2007 (75)	3825 (58)	-2.4 (37)	+12.9 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.2 (27) -.8 (124)	8.6 (97)

CROSSWIND (8)

RUNID -149

PLOTID 842

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		28	703 (58)	1961 (75)	4143 (58)	+8.1 (112)	+12.0 (60)	-10.0 (26)	-1.7 (116)	+1.6 (58)	+9.1 (27)	-1.5 (126)
	✓	✓			✓				700 (58)	2008 (75)	3965 (58)	+8.1 (112)	+12.5 (70)	-10.0 (26)	-1.7 (115)	+1.6 (58)	+9.2 (27)	-1.8 (124)
✓			✓		✓				694 (58)	1844 (75)	4051 (58)	+3.8 (112)	+12.1 (60)	-10.0 (26)	-1.3 (116)	+1.6 (58)	+9.1 (27)	-2.8 (122)
	✓		✓		✓				692 (58)	1891 (75)	3985 (58)	+3.8 (112)	+12.6 (70)	-10.0 (26)	-1.3 (116)	+1.6 (58)	+9.2 (27)	-1.5 (124)
✓		✓		✓					702 (58)	1961 (75)	4001 (58)	+2.3 (84)	+12.3 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.1 (27)	-2.3 (126)
	✓	✓		✓					700 (58)	2007 (75)	3828 (58)	-2.4 (37)	+12.9 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.1 (27)	-3.6 (125)
✓			✓	✓					702 (58)	1961 (75)	4002 (58)	+2.3 (84)	+12.3 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.1 (27)	-3.9 (122)
	✓		✓	✓					700 (58)	2007 (75)	3827 (58)	-2.4 (37)	+12.9 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.2 (27)	-.8 (124)

CROSSWIND (28)

RUNID -151

PLOTID 850

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		56	702 (58)	2008 (75)	4099 (58)	-8.0 (112)	+12.1 (60)	-10.0 (26)	-1.7 (116)	-1.5 (58)	+9.1 (27)	[illegible]
	✓	✓			✓				700 (58)	2053 (75)	3928 (58)	+8.0 (112)	+12.7 (70)	-10.0 (26)	-1.7 (115)	+1.6 (58)	+9.2 (27)	[illegible]
✓			✓		✓				701 (58)	1968 (61)	4201 (58)	+3.8 (112)	+12.2 (60)	-10.0 (26)	+2.5 (60)	+1.2 (58)	+9.1 (27)	[illegible]
	✓		✓		✓				699 (58)	1955 (61)	4037 (58)	+3.7 (112)	+12.7 (70)	-10.0 (26)	+2.5 (60)	+1.2 (58)	+9.2 (27)	8.6 (97)
✓		✓		✓					702 (58)	196[illegible] (75)	3952 (58)	+2.3 (84)	+12.3 (70)	-10.0 (26)	+1.0 (70)	-1.7 (58)	+9.1 (27)	5.5 (176)
	✓	✓		✓					700 (58)	2007 (75)	[illegible] (58)	-2.4 (36)	+12.9 (70)	-10.0 (26)	-1.0 (70)	+1.7 (58)	[illegible]	3.6 (97)
✓			✓	✓					702 (58)	1961 (75)	[illegible] (58)	+2.3 (84)	+12.3 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	[illegible] (27)	[illegible]
	✓		✓	✓					700 (58)	2007 (75)	3810 (58)	-2.4 (36)	+12.9 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	15.2 (27)	[illegible]

CROSSWIND (1.5)

RUNID -156

PLOTID 291

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		58	702 (58)	2012 (75)	3998 (58)	+8.0 (112)	+12.2 (60)	+10.0 (26)	-1.7 (116)	+1.7 (58)	[illegible] (27)	7.6 (126)
	✓	✓			✓				700 (58)	2056 (75)	3824 (58)	+8.0 (112)	+12.7 (70)	-10.0 (26)	-1.7 (115)	+1.7 (58)	+9.2 (27)	-1.8 (124)
✓			✓		✓				702 (58)	1877 (75)	3998 (58)	+3.8 (112)	+12.1 (70)	-10.0 (26)	+1.5 (61)	+1.7 (58)	+9.1 (27)	-2.8 (112)
	✓		✓		✓				700 (58)	1923 (75)	3824 (58)	+3.7 (112)	+12.7 (70)	-10.0 (26)	+1.5 (61)	+1.7 (58)	+9.2 (27)	-5 (124)
✓		✓		✓					702 (58)	1960 (75)	3998 (58)	+2.3 (84)	+12.5 (60)	-10.0 (26)	+1.0 (27)	+1.8 (58)	+9.1 (27)	[illegible]
	✓	✓		✓					700 (58)	2007 (75)	3824 (58)	-2.4 (37)	+12.9 (60)	-10.0 (26)	+1.0 (70)	+1.8 (58)	+9.2 (27)	-3.6 (125)
✓			✓	✓					702 (58)	1961 (75)	[illegible] (58)	+2.3 (84)	+12.5 (60)	-10.0 (26)	+1.0 (70)	+1.8 (58)	+9.1 (27)	[illegible]
	✓		✓	✓					700 (58)	[illegible] (75)	3824 (58)	-2.4 (37)	+12.9 (60)	+9.2 (27)	+1.0 (70)	+1.8 (58)	+9.2 (27)	[illegible]

CROSSWIND (58)

RUNID -153

PLOTID [illegible]

A47

x

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 - 127 SEC) PITCH SRM GAIN OFF AT 61										
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS	BMAX
✓		✓			✓	✓		60	702 (58)	2028 (74)	3998 (58)	+3.3 (97)	+12.3 (60)	-10.2 (26)	+1.1 (62)	+1.7 (58)	+9.1 (27)	-3.4 (23)	+8.1 (97)
	✓	✓			✓				700 (58)	2076 (74)	3824 (58)	+3.3 (97)	+12.8 (60)	-10.0 (26)	+1.1 (62)	+1.7 (58)	+9.2 (27)	-1.8 (124)	+8.6 (97)
✓			✓		✓				702 (58)	1777 (75)	3998 (58)	-2.2 (36)	+12.3 (60)	-10.0 (26)	+1.5 (63)	+1.7 (58)	+9.1 (27)	-2.5 (122)	+8.7 (123)
	✓		✓		✓				700 (58)	+1824 (75)	3824 (58)	-2.4 (37)	+12.8 (60)	-10.0 (26)	+1.5 (63)	+1.7 (58)	+9.2 (27)	-1.5 (124)	+8.6 (124)
✓		✓		✓					702 (58)	+1960 (75)	3998 (58)	+2.3 (84)	+12.3 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.1 (27)	-4.0 (126)	+8.5 (123)
	✓	✓		✓					700 (58)	2007 (75)	3824 (58)	-2.4 (37)	+12.9 (70)	+14.1 (124)	+1.0 (70)	+1.7 (58)	+9.2 (27)	-4.9 (125)	+8.6 (97)
✓			✓	✓					702 (58)	1960 (75)	3998 (58)	+2.3 (84)	+12.3 (70)	-15.4 (127)	+1.0 (70)	+1.7 (58)	+9.1 (27)	-6.0 (123)	+10.8 (123)
	✓		✓	✓					700 (58)	2007 (75)	3824 (58)	-2.4 (37)	+12.9 (70)	-10.0 (26)	+1.0 (70)	+1.7 (58)	+9.2 (27)	-1.9 (124)	+8.6 (97)

CROSSWIND PSRM = 0 (60

RUNID 166
PLOTID 156

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		60	656 (58)	175[illegible] (72)	1393 (24)	+2.5 (85)	+3.[illegible] (62)	-9.8 (25)	+1.1 (62)	+1.1 (2[illegible])	+2.2 (27)	
	✓	✓			✓				653 (57)	1821 (75)	1427 (25)	+2.4 (86)	+4.0 (70)	-9.9 (25)	+1.1 (63)			
✓			✓		✓				656 (58)	1706 (74)	1393 (24)	-2.2 (36)	+3.4 (65)	-9.8 (25)	+1.3 (63)			
	✓		✓		✓				653 (57)	1741 (74)	1427 (25)	-2.4 (37)	+3.9 (70)		+1.3 (63)			
✓		✓		✓					656 (58)	181[illegible] (7[illegible])	1393 (24)	+2.4 (83)	+3.4 (70)		+1.0 (70)			
	✓	✓		✓					653 (57)	1914 (77)	1427 (25)	-2.4 (37)	+4.0 (70)	+14.3 (124)		-1.5 (124)		
✓			✓	✓					656 (58)	1872 (71)	1393 (24)	+2.4 (83)	+3.4 (70)	-13.9 (124)		+1.4 (124)		
	✓		✓	✓					653 (57)	191[illegible] (77)	1427 (25)	-2.4 (37)	+4.0 (70)	-9.8 (25)		+1.1 (21)		

No W[illegible]

RUNID ____

PLOTID ____

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									Z ACC = 0 REDUCED PITCH GAINS
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		57	730 (59)	1252 (60)	4010 (58)	+1.8 (95)	+12.1 (60)	-10.0 (26)	+1.3 (59)	+1.5 127	+9.1 (27)	
	✓	✓			✓				729 (59)	1314 (60)	3865 (58)	1.9 (95)	+12.6 (70)	-10.0 (26)	+1.4 (59)	+1.4 (59)	+9.2 (27)	
✓			✓		✓				730 (58)	-1229 (60)	4058 (58)	-2.1 (60)	+12.2 (61)	-10.0 (26)	+2.3 (61)	+1.4 (127)	+9.1 (27)	
	✓		✓		✓				729 (58)	-1123 (60)	3904 (58)	-2.1 (59)	+12.6 (71)	-10.0 (26)	+2.3 (61)	+1.3 (59)	+9.2 (27)	
✓		✓		✓					730 (59)	-852 (29)	3923 (58)	+1.7 (47)	+12.3 (60)	-10.0 (26)	+.8 (51)	+1.6 (59)	+9.1 (27)	
	✓	✓		✓					729 (59)	-728 (30)	3815 (58)	+1.7 (122)	+12.8 (70)	+10.2 (124)	-1.0 (124)	+1.7 (59)	+9.2 (27)	
✓			✓	✓					730 (59)	-852 (29)	3926 (58)	+1.7 (47)	+12.[illegible] ([illegible])	-10.9 (124)	+.9 (124)	+1.6 (59)	+9.1 (27)	
	✓		✓	✓					729 (59)	-728 (30)	3815 (58)	+1.6 (47)	[illegible] (70)	-10.0 (26)	+.8 (52)	+1.7 (59)	+9.2 (27)	

CROSS-[illegible] $\ddot{Z}_{GAIN} = 0$

RUNID -173

PLØTID 1[illegible]

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	MAXIMUM VALUES DURING BOOST (0 – 127 SEC)									
L	R	L	R	Y	P.	YES	NO		Q (#/FT²)	Qα (#-°/FT²)	Qβ (#-°/FT²)	Θ_ε (°)	ψ_ε (°)	ϕ_ε (°)	$\dot{\Theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	COMMENTS
✓		✓			✓	✓		57	773 (58)	-2143 (58)	1945 (23)	+3.1 (60)	+3.4 (70)	-11.1 (26)	+1.5 (59)	+1.1 (27)	+9.4 (28)	
	✓	✓			✓				771 (58)	-212.6 (58)	1955 (23)	+3.0 (60)	+3.[illegible] (70)	-11.4 (26)	+1.5 (59)	+1.2 (27)	+9.4 (28)	
✓			✓		✓				773 (58)	-236[illegible] (58)	1945 (23)	+2.8 (60)	+3.[illegible] (70)	-11.1 (26)	+1.5 (59)	+1.1 (27)	+9.4 (28)	
	✓		✓		✓				771 (58)	-2325 (58)	195[illegible] (23)	+2.8 (60)	+3.9 (70)	-11.4 (26)	+1.5 (59)	+1.2 (27)	+9.4 (28)	
✓		✓		✓					773 (58)	-2157 (58)	1946 (23)	+2.6 (60)	+3.4 (70)	-11.1 (26)	+1.2 (59)	+1.1 (27)	+9.4 (28)	
	✓	✓		✓					771 (58)	-2121 (58)	1955 (23)	+2.5 (59)	+4.1 (123)	-11.4 (26)	+1.2 (59)	+1.2 (27)	+9.4 (28)	
✓			✓	✓					773 (58)	-2157 (58)	1946 (23)	+2.6 (60)	-3.6 (123)	-11.1 (26)	+1.2 (59)	+1.2 (124)	+9.4 (28)	
	✓		✓	✓					771 (58)	-2121 (58)	1955 (23)	+2.5 (59)	+3.[illegible] (7[illegible]	-11.4 (26)	+1.2 (59)	+1.2 (27)	+9.4 (28)	

HEADW[illegible] (5[illegible]) [illegible] = 0

RUNID -176

PLOTID __

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
									DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\varphi}$	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓	✓		0.1	21	49	65	-8.5	7.8	-.3	.3	-.2	4.4	
	✓	✓			✓	✓		0.1	20	50	63	-9.5	6.7	-.1	-.2	.3	4.4	
✓			✓		✓	✓		0.1	49	22	58	-7.2	8.2	-.0	.3	-.1	4.3	
	✓		✓		✓	✓		0.1	52	21	57	-8.2	7.2	-.2	-.3	.4	4.3	
✓		✓		✓		✓		0.1	26	59	56	-6.6	8.4	-.2	.4	-.4	4.3	
	✓	✓		✓		✓		0.1	27	57	55	-7.3	7.9	-.2	-.1	-.4	4.3	
✓			✓	✓		✓		0.1	54	28	56	-7.1	8.1	-.2	.3	-.6	4.3	
	✓		✓	✓		✓		0.1	55	30	55	-7.7	7.6	-.1	-.2	.4	4.3	

CROSSWIND (LW

RUNID -143

PLOTID 152

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.2 SEC)									
L	R	L	R	Y	P.	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	$\dot{\theta}$ (°/SEC)	$\dot{\psi}$ (°/SEC)	$\dot{\phi}$ (°/SEC)	M	COMMENTS
✓		✓			✓	✓		8	22	48	65	-8.4	+7.8 (+5.5)	-.3 (-.02)	+.4 (+.09)	-.4 (-.001)	4.4	>14[illegible]
	✓	✓			✓				21	51	64	-9.4	+6.5 (+5.8)	-.08 (-.02)	+.03 (+.07)	+.1 (+.03)	4.4	
✓			✓		✓				55	26	59	-7.2	+8.2 (6.2)	-.03 (-.02)	+.3 (+.1)	+.04 (-.001)	4.3	
	✓		✓		✓				56	24	58	-8.0	+7.0 (+6.4	-.2 (-.02)	-.04 (+.1)	+.4 (+.03)	4.3	
✓		✓		✓					26	58	57	-6.5	+8.5 (6.3)	-.2 (-.02)	+.4 (+.1)	-.6 (0)	4.3	
	✓	✓		✓					27	57	56	-7.1	+7.8 (+6.4)	-.2 (-.01)	+.1 (+.09)	-.7 (0)	4.3	
✓			✓	✓					53	29	57	-7.0	+8.1 (+6.4)	-.2 (-.02)	+.2 (+.1)	-.6 (-.02)	4.3	
	✓		✓	✓					55	30	56	-7.6	+7.4 (+6.5)	-.2 (-.01)	+.01 (+.08)	+.3 (+.02)	4.3	

YAW GAIN RAMPED OFF 125-127

(R. [illegible]/8)

RUNID 149

PLOTID 342

STAGING CONDITIONS (127.0 SEC)

Y ACCEL ON AT 127
YAW ATT GAIN RAMP OFF 125-127

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	DCYCLE		Q	α	β	θ̇	ψ̇	φ̇	M	COMMENTS STAGING T.Y =
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓	✓		28	24	45	65	-8.4	+8.0 (+5.0)	-.3 (-.06)	+.4 (+.7)	-.4 (-1.4)	4.4	(131.9)
	✓	✓			✓				23	47	64	-9.4	+6.7 (+5.0)	-.07 (-.02)	+.03 (+.7)	+.1 (+.03)	4.4	(131.0)
✓			✓		✓				47	25	58	-7.2	+8.1 (+5.0)	-.03 (-.06)	+.3 (+.6)	+.05 (+1.2)	4.3	(132.2)
	✓		✓		✓				48	24	57	-8.0	+6.9 (+5.0)	-.2 (-.01)	-.05 (+.6)	+.4 (-.04)	4.3	(131.4)
✓		✓		✓					29	56	57	-6.5	+8.5 (+4.9)	-.2 (-.08)	-.4 (+.5)	-.6 (+1.3)	4.3	(133.3)
	✓	✓		✓					30	55	56	-7.1	+7.8 (+5.0)	-.2 (-.05)	+.2 (-.5)	-.7 (+.6)	4.3	(133.6)
✓			✓	✓					51	32	57	-7.0	+8.1 (+5.0)	-.2 (-.05)	+.2 (+.5)	-.6 (+.9)	4.3	(133.4)
	✓		✓	✓					52	33	56	-7.6	+7.4 (+5.0)	-.2 (-.02)	+.01 (+.5)	+.3 (+.1)	4.3	(132.3)

CROSSWIND 70
RUNID -151
PLOTID 850

STAGING CONDITIONS (127.2 SEC)

Y ACCEL ON AT 127
YAW AIT GAIN RAMP OFF 125-127

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓	✓		56	28	48	64	-8.2	+8.1 (+5.0)	-.3 (-.06)	+.4 (+.6)	-.4 (+1.4)	4.4	(132.1)
	✓	✓			✓				28	51	62	-7.3	+6.8 (+5.0)	-.07 (-.02)	+.03 (+.6)	-.1 (+.1)	4.4	(131.3)
✓			✓		✓				58	36	57	-7.1	+7.2 (+5.0)	-.03 (-.05)	+.3 (+.5)	+.05 (+1.2)	4.3	(132.3)
	✓		✓		✓				55	35	56	-8.0	+7.0 (+5.0)	-.2 (-.01)	-.05 (+.5)	+.4 (-.03)	4.3	(131.6)
✓		✓		✓					31	55	51	-6.5	+8.4 (4.9)	-.2 (-.01)	+.4 (+.5)	-.6 (+1.3)	4.3	(133.1)
	✓	✓		✓					31	53	56	-7.1	+7.8 (+5.0)	-.2 (-.04)	+.2 (+.5)	-.7 (+.6)	4.3	(133.6)
✓			✓	✓					50	33	57	-7.0	+8.1 (+5.0)	-.2 (-.05)	+.2 (+.5)	-.6 (+.9)	4.3	(133.[illegible])
	✓		✓	✓					50	35	56	-7.5	+7.4 (+5.0)	-.2 (-.02)	+.01 (+.5)	+.3 (+.1)	4.3	(132.3)

CROSSWIND (56)

RUNID -156

PLØTID 291

STAGING CONDITIONS (127.0 SEC)

Y ACCEL ON AT 127
YAW AT GAIN
RAM 05 125-127

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓	✓		58	29	45	64	-8.2	+8.1 (+5.0)	-.3 (-.06)	+.4 (+.6)	-.4 (+1.4)	4.4	(132.1)
	✓	✓			✓				29	48	62	-9.3	+6.8 (+5.0)	-.07 (-.02)	+.03 (+.6)	+.1 (+.09)	4.4	(131.3)
✓			✓		✓				46	35	58	-7.2	+8.2 (+5.0)	-.03 (-.05)	+.3 (+.5)	+.04 (+1.2)	4.3	(132.3)
	✓		✓		✓				48	34	57	-8.0	+6.9 (+5.0)	-.2 (-.01)	-.05 (+.6)	+.4 (-.03)	4.3	(131.6)
✓		✓		✓					31	54	57	-6.5	+8.5 (+4.9)	-.2 (-.07)	+.4 (+.5)	-.6 (+1.3)	4.3	(133.3)
	✓	✓		✓					32	52	56	-7.1	+7.8 (+5.0)	-.2 (-.05)	+.2 (+.5)	-.7 (+.6)	4.3	(133.6)
✓			✓	✓					49	34	51	-7.0	+8.1 (+5.0)	-.2 (-.05)	+.2 (+.5)	-.6 (+.9)	4.3	(133.4)
	✓		✓	✓					49	36	56	-7.6	+7.4 (+5.0)	-.2 (-.02)	+.01 (+.5)	+.3 (+.1)	4.3	(132.3)

CROSSWIND (58)

RUNID -153

PLOTID 861

STAGING CONDITIONS (127.0 SEC)

YACCEL. ON AT 124 SEC
YAW AT GAIN
RAMP OFF
123-125

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		STAGING TIME
✓		✓			✓	✓		60	30	45	64	-7.6	+6.4 (+4.9)	-.3 (-.1)	+1.5 (+.9)	-.4 (+1.4)	4.4	(128.3)
	✓	✓			✓				30	48	63	-8.7	+6.4 (+5.0)	-.07 (-.04)	+.5 (+.7)	-.5 (-.1)	4.4	(129.8)
✓			✓		✓				48	37	56	-6.6	+5.4 (+4.9)	-.008 (-.01)	+1.4 (+1.2)	+.9 (+1.5)	4.3	(127.4)
	✓		✓		✓				50	36	55	-7.5	+6.8 (+5.0)	-.2 (-.02)	+.4 (+.6)	-.4 (-.09)	4.3	(130.8)
✓		✓		✓					32	50	56	-6.1	+6.4 (+5.0)	-.2 (-.04)	+1.4 (+.8)	-1.0 (+1.0)	4.3	(128.4)
	✓	✓		✓					(33)	(46)	(65)	(-7.6)	(+4.9)	(-.6)	(+.7)	(-5.1)	4.3	(125.0)
✓			✓	✓					46	36	56	-5.0	+8.3 (+5.0)	-.2 (-.06)	+1.6 (+.6)	-1.8 (+.9)	4.3	(130.9)
	✓		✓	✓					46	38	55	-7.5	+7.2 (+5.0)	-.2 (-.02)	+.4 (+.6)	-.1 (-.007)	4.3	(131.1

CROSSWIND (60) PSRM = 0

RUNID -166

PLOTID 156

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (125.0 SEC)									
									DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		
✓		✓			✓	✓		60	24	37	65	-6.0	+2.3	-.5	-.07	-2.3	4.3	(125.0)
	✓	✓			✓				25	36	63	-7.3	+1.6	-.07	-.3	+.2	4.3	
✓			✓		✓				37	27	62	-6.9	+1.9	-.2	+.5	-.8	4.3	
	✓		✓		✓				40	27	61	-6.3	+1.5	-.4	+.08	+2.1	4.3	
✓		✓		✓					27	40	62	-6.2	+2.0	-.5	+.4	-2.1	4.3	
	✓	✓		✓					26	37	61	-6.3	-.6	-.6	+.5	-4.3	4.3	
✓			✓	✓					36	27	62	-5.6	+4.1	-.5	-.2	+3.3	4.3	
	✓		✓	✓					38	29	61	-6.1	+1.8	-.5	-.4	+1.8	4.3	

NO WIND (6) PSNM = 0

RUNID 166

PLOTID 118

STAGING CONDITIONS (127.2 SEC)

YACCEL OL ≈ 12.4
YAF GAIN HARDEN OF = 12[illegible]
YNA[illegible]

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	DCYCLE		Q	α	β	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$	M	COMMENTS
L	R	L	R	Y	P.	YES	NO		L	R	(#/FT²)	(°)	(°)	(°/SEC)	(°/SEC)	(°/SEC)		STAGING TIME
✓		✓			✓	✓		57	27	46	65	-7.1 (-7.6)	+6.8 (+5.0)	-.3 (-.1)	+1.5 (+1.4)	-1.5 (+.6)	4.4	(128.4)
	✓	✓			✓				(27)	(49)	(67)	(-8.2)	(+5.0)	(-.04)	(+.8)	(+.08)	4.4	(126.6)
✓			✓		✓				59	35	57	-6.5 (-6.7)	+6.0 (+5.0)	-.06 (-.05)	+1.4 (+1.3)	-.3 (+.4)	4.4	(127.8)
	✓		✓		✓				(58)	(55)	(59)	(-7.2)	(+5.0)	(-.2)	(+.6)	(+1.0)	4.4	(126.8)
✓		✓		✓					30	52	58	-6.3 (-6.7)	+6.8 (+4.9)	-.2 (-.07)	+1.5 (+1.3)	-1.4 (+.8)	4.4	(128.5)
	✓	✓		✓					(30)	(47)	(68)	(-7.0)	(+4.2)	(-.66)	(-.05)	(-4.0)	4.4	(125.0)
✓			✓	✓					48	33	58	-6.3 (-7.0)	+7.3 (+4.9)	-.2 (-.09)	+1.3 (+1.2)	+.8 (+.9)	4.4	(128.9)
	✓		✓	✓					49	34	58	-7.2 (-7.5)	+5.4 (+5.0)	-.2 (-.2)	+.7 (+.7)	+.5 (+.05)	4.4	(127.7)

(ROSS[illegible] (57) $\ddot{z}_{GO}$

RUNID -173

PLOTTED 180

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	STAGING CONDITIONS (127.0 SEC)									
L	R	L	R	Y	P.	YES	NO		DCYCLE L	DCYCLE R	Q (#/FT²)	α (°)	β (°)	θ̇ (°/SEC)	ψ̇ (°/SEC)	φ̇ (°/SEC)	M	COMMENTS
✓		✓			✓	✓		57	24	35	67	-6.6						(125.0
	✓	✓			✓				24	35	67	-7.5						
✓			✓		✓				35	26	65	-7.1	+2.3	-.2	+.2	+.5	4.4	
	✓		✓		✓				38	26	65	-6.6	+1.0	-.4	+.3	+1.1	4.4	
✓		✓		✓					27	41	63	-6.4						
	✓	✓		✓					26	36	63	-6.5	....					
✓			✓	✓					35	27	63	-5.9						
	✓		✓	✓					38	29	63	-6.4	+1.1	-.5	-.09	+.4	4.4	

HEADWIND (57) $\tilde{z} = 0$

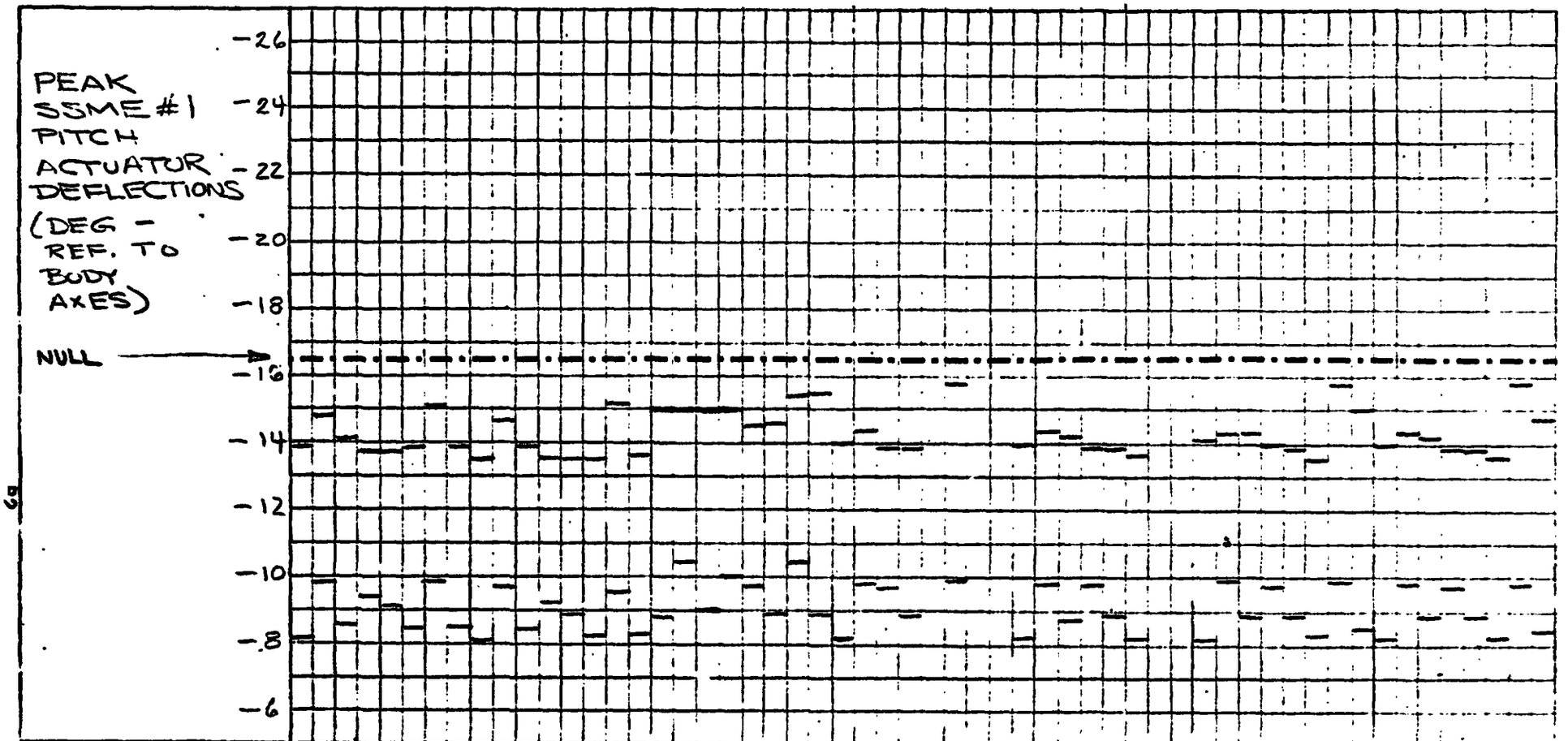
RUNID 176

PLOTID 310

APPENDIX B1

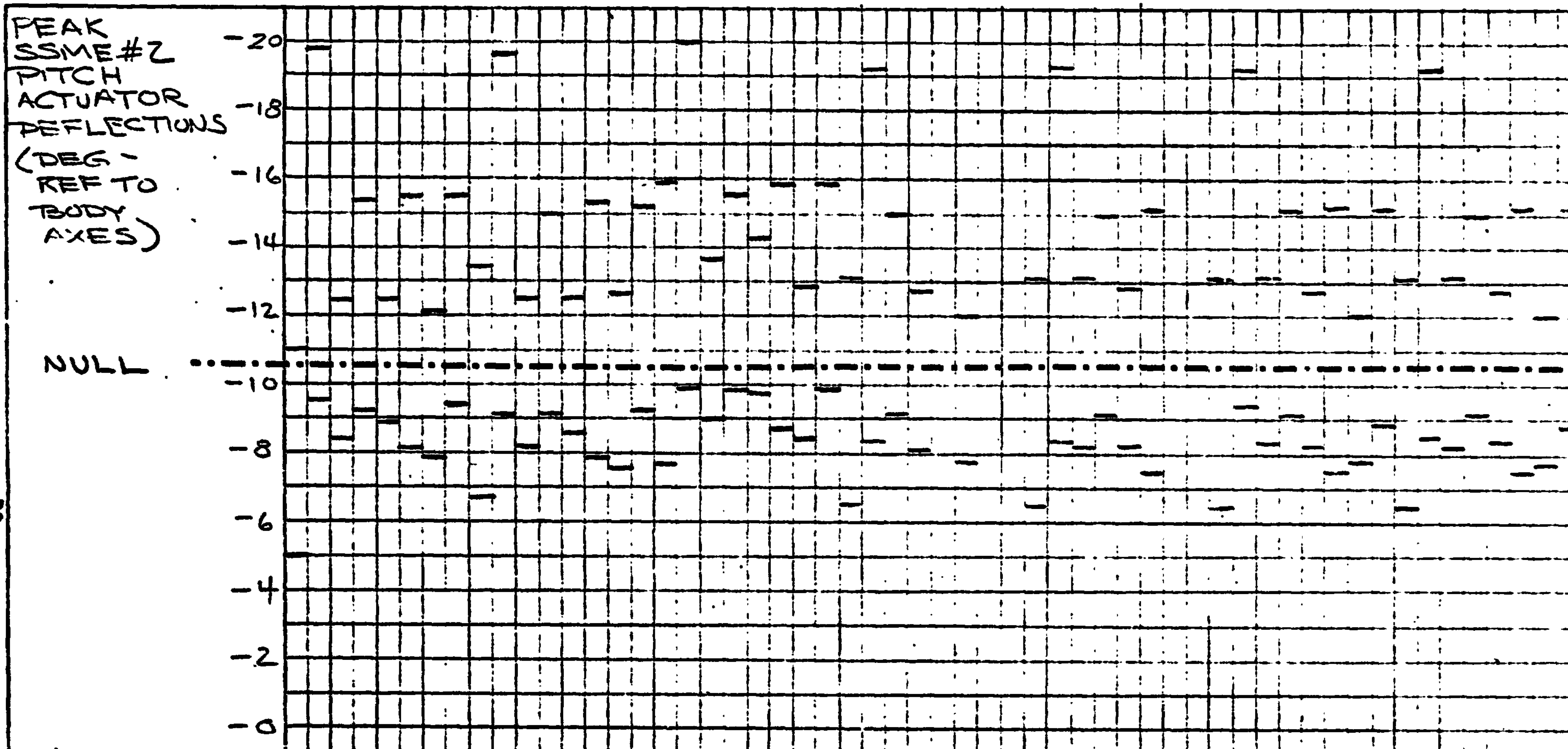
SSME DEFLECTION ENVELOPES
45° - 135° TVC BASELINE SYSTEM

MAXIMUM SSME ACTUATOR DEFLECTIONS (0-127 SECS)



TIME OF ACTUATOR FAILURE	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 8 8 8 8 8 8 8 8 26 26 26 26 26 26 26 26 57 57 57 57 57 57 57 57			
SRM W/ HIGH THR. AT LIFTOFF	L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R L R			
SRM W/ FAILED ACTUATOR	L L R R L L R R L L R R L L R R L L R R L L R R L L R R L L R R L L R R L L R R L L R R L L R R L L R R L L R R L L R R			
ACTUATOR FAILED	R R R R L L L L R R R R L L L L R R R R L L L L R R R R L L L L R R R R L L L L R R R R L L L L			
WIND	NO WIND	HEADWIND (42 M/S)	TAILWIND (75 M/S)	RIGHT CROSSWIND (60 M/S)

MAXIMUM SSME ACTUATOR DEFLECTIONS (0 - 127 SECS)



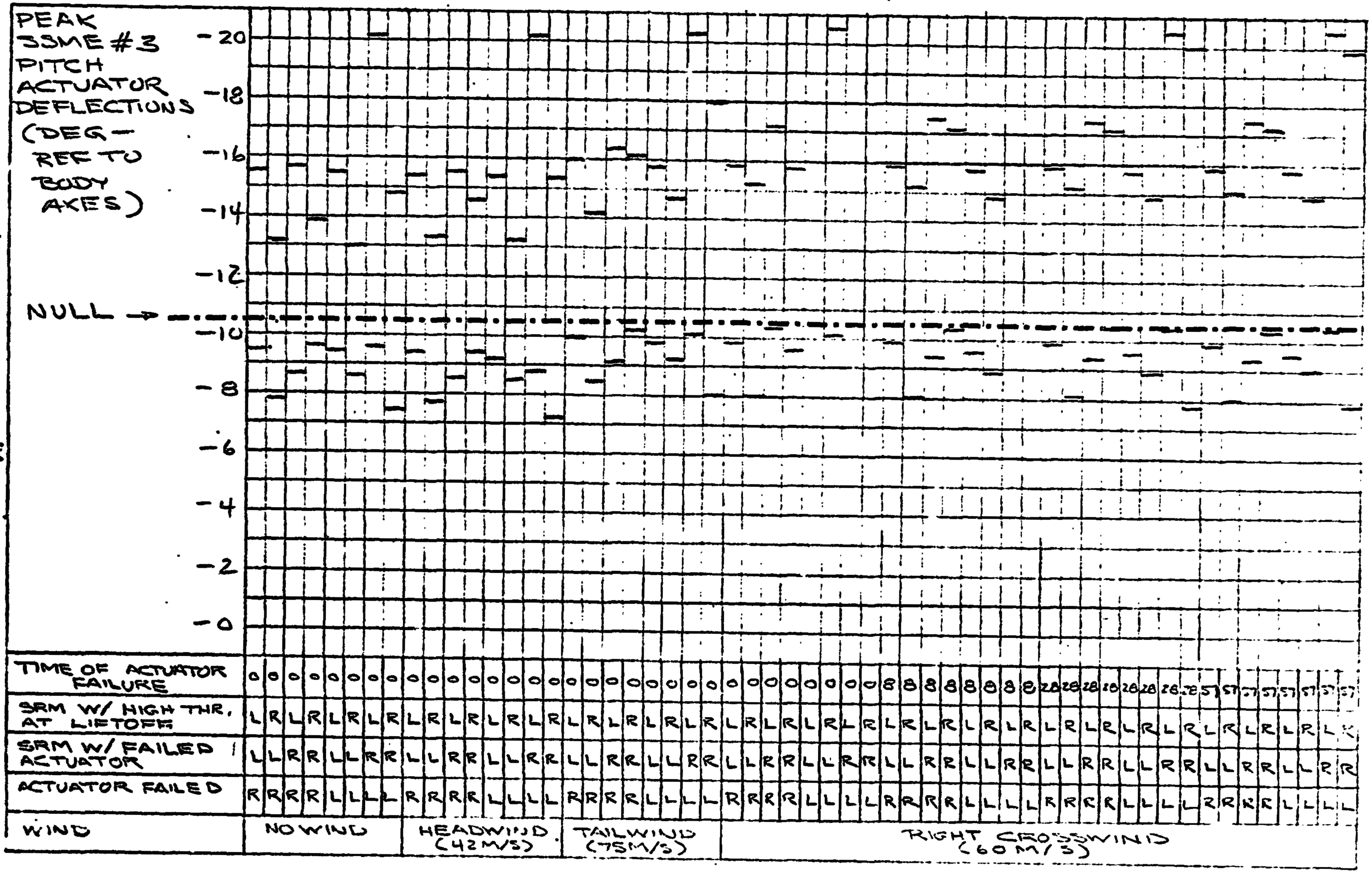
WIND	NO WIND							
TIME OF ACTUATOR FAILURE	0	0	0	0	0	0	0	0
SRM W/ HIGH THR. AT LIFTOFF	L	R	L	R	L	R	L	R
SRM W/ FAILED ACTUATOR	L	L	R	R	L	L	R	R
ACTUATOR FAILED	R	R	R	R	L	L	L	L

WIND	HEADWIND (42M/S)							
TIME OF ACTUATOR FAILURE	0	0	0	0	0	0	0	0
SRM W/ HIGH THR. AT LIFTOFF	L	R	L	R	L	R	L	R
SRM W/ FAILED ACTUATOR	L	L	R	R	L	L	R	R
ACTUATOR FAILED	R	R	R	R	L	L	L	L

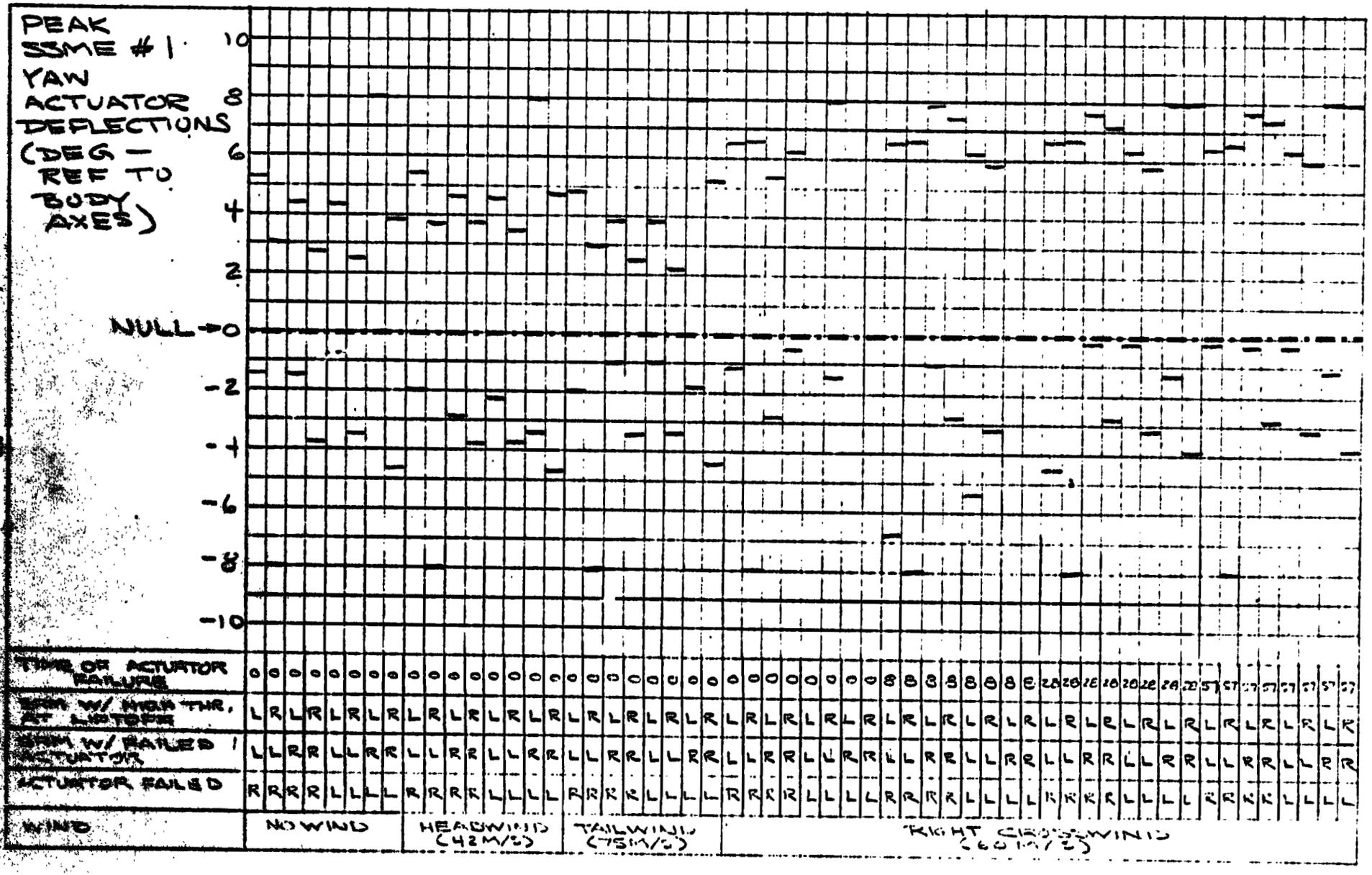
WIND	TAILWIND (75M/S)							
TIME OF ACTUATOR FAILURE	0	0	0	0	0	0	0	0
SRM W/ HIGH THR. AT LIFTOFF	L	R	L	R	L	R	L	R
SRM W/ FAILED ACTUATOR	L	L	R	R	L	L	R	R
ACTUATOR FAILED	R	R	R	R	L	L	L	L

WIND	RIGHT CROSSWIND (60M/S)																															
TIME OF ACTUATOR FAILURE	0	0	0	0	0	0	0	0	8	8	8	8	8	8	8	8	28	28	28	28	28	28	28	28	57	57	57	57	57	57	57	57
SRM W/ HIGH THR. AT LIFTOFF	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
SRM W/ FAILED ACTUATOR	L	L	R	R	L	L	R	R	L	L	R	R	L	L	R	R	L	L	R	R	L	L	R	R	L	L	R	R	L	L	R	R
ACTUATOR FAILED	R	R	R	R	L	L	L	L	R	R	R	R	L	L	L	L	R	R	R	R	L	L	L	L	R	R	R	R	L	L	L	L

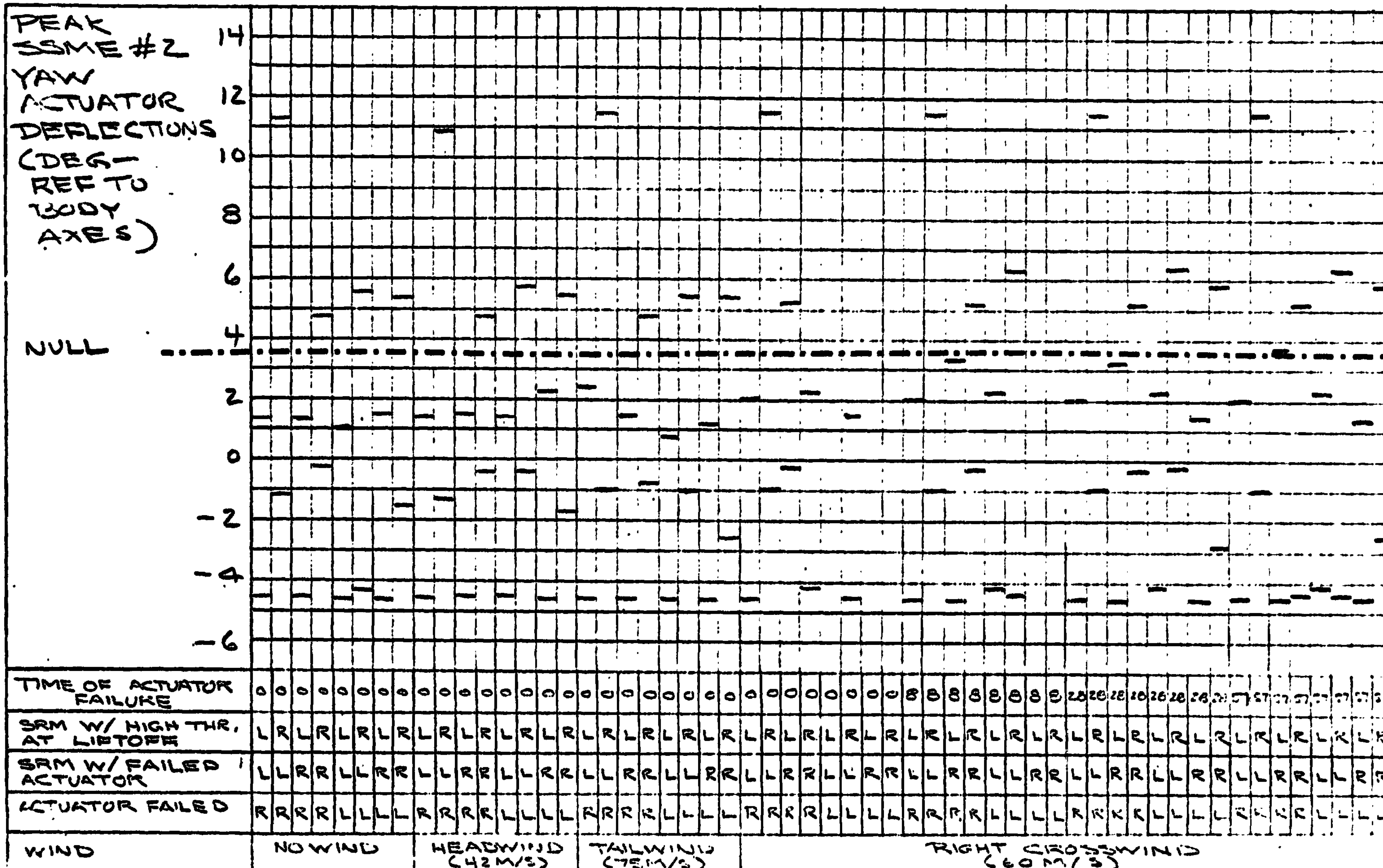
MAXIMUM SSME ACTUATOR DEFLECTIONS (0 – 127 SECS)



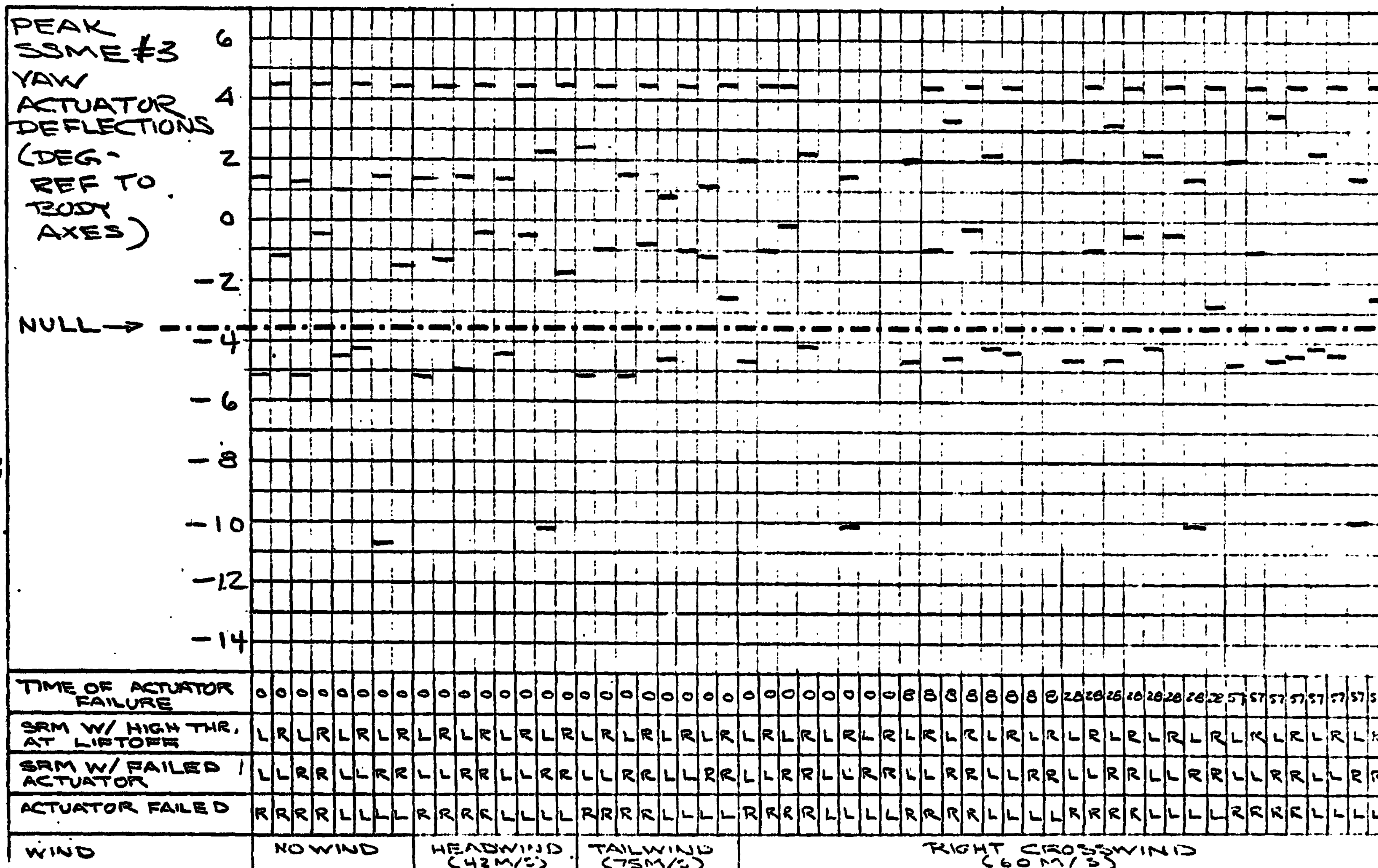
MAXIMUM SSME ACTUATOR DEFLECTIONS (0 - 127 SECS)



MAXIMUM SSME ACTUATOR DEFLECTIONS (0 - 127 SECS)



MAXIMUM SSME ACTUATOR DEFLECTIONS (0 – 127 SECS)



MAXIMUM SSME DEFLECTIONS

	PITCH ACTUATOR		YAW ACTUATOR	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
SSME #1	-8.2°	-15.1°	8.0°	-8.0°
SSME #2	-7.0°	-19.8°	11.2°	-4.5°
SSME #3	-7.4°	-20.1°	4.5°	-10.7°

NO WIND FAILURES AT T = 0.1

ANGLES REFERENCED TO BODY AXES

MAXIMUM SSME DEFLECTIONS

	PITCH ACTUATOR		YAW ACTUATOR.	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
SSME #1	-8.8	-15.5	8.0	-8.0
SSME #2	-7.7	-20.0	11.5	-4.5
SSME #3	-8.0	-20.2	4.5	-5.1

TAILWIND (75 M/S) FAILURES AT T = 0.1

ANGLES REFERENCED TO BODY AXES

MAXIMUM SSME DEFLECTIONS

	PITCH ACTUATOR		YAW ACTUATOR.	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
SSME #1	-8.1	-15.1	8.0	-8.0
SSME #2	-6.7	-19.7	10.9	-4.5
SSME #3	-7.2	-20.1	4.5	-10.2

HEADWIND (42 M/S) FAILURES AT T= 0.1

ANGLES REFERENCED TO BODY AXES

MAXIMUM SSME DEFLECTIONS

	PITCH ACTUATOR		YAW ACTUATOR.	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
SSME #1	-8.2	-15.8	8.0	-8.0
SSME #2	-6.5	-19.2	11.5	-4.5
SSME #3	-7.8	-20.5	4.5	-10.0

RIGHT XWIND (60 M/S) FAILURES AT T=57

ANGLES REFERENCED TO BODY AXES

MAXIMUM SSME DEFLECTIONS

	PITCH ACTUATOR		YAW ACTUATOR.	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
SSME #1	-8.2	-15.8	8.0	-8.0
SSME #2	-6.5	-19.2	11.5	-4.5
SSME #3	-7.8	-20.5	4.5	-10.1

RIGHT XWIND (60 M/S) FAILURES AT T=28

ANGLES REFERENCED TO BODY AXES

MAXIMUM SSME DEFLECTIONS

	PITCH ACTUATOR		YAW ACTUATOR.	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
SSME #1	-8.2	(-15.8)	(8.0)	-8.0
SSME #2	-6.5	-19.2	11.5	-4.5
SSME #3	(-7.8)	(-20.5)	4.5	(-10.1)

RIGHT XWIND (60 M/S) FAILURES. AT T = 8

ANGLES REFERENCED TO BODY AXES

( ) THESE PEAKS ASSUMED FROM FAILURE DATA AT 28 SEC — NO DATA FROM 8 SEC

MAXIMUM SSME DEFLECTIONS

	PITCH ACTUATOR		YAW ACTUATOR.	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
SSME #1	-8.2	(-15.8)	8.0	-8.0
SSME #2	-6.5	-19.2	11.5	-4.5
SSME #3	(-7.8)	-20.5	4.5	-10.1

RIGHT XWIND (60 M/S) FAILURES AT T=0.1

ANGLES REFERENCED TO BODY AXES

( ) THESE PEAKS ASSUMED FROM FAILURE DATA AT 28 SEC - NO DATA FROM 0.1 SEC

MAXIMUM SSME DEFLECTIONS

	PITCH ACTUATOR		YAW ACTUATOR	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
SSME #1	+8.4°	0	8.0°	-8.0°
SSME #2	4.0°	-9.5°	8.0°	-8.0°
SSME #3	3.3°	-10.0°	8.0°	-7.2°

ANGLES REFERENCED TO INDIVIDUAL ENGINE NULL POSITIONS OF

	PITCH	YAW
#1	-16.5°	0°
#2, #3	-10.5°	3.5° outboard

MAXIMUM SSME DEFLECTIONS

	PITCH ACTUATOR		YAW ACTUATOR	
	POSITIVE	NEGATIVE	POSITIVE	NEGATIVE
SSME #1	-8.1°	-15.8°	8.0°	-8.0°
SSME #2	-6.5°	-20.0°	11.5°	-4.5°
SSME #3	-7.2°	-20.5°	4.5°	-10.7°

ANGLES REFERENCED TO BODY AXES

ORIGINAL PAGE IS POOR,

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	SEME DEFLECTION MAXIMUM VALUES DURING BOOST (0 – 127 SEC)					
L	R	L	R	L	R	YES	NO		#1 PITCH	#2 PITCH	#3 PITCH	#1 YAW	#2 YAW	#3 YAW
✓		✓			✓		✓	0.1	-8.2@116	-7.0@116	-9.5@116	5.2@122	1.3@56	1.3@56
									-13.9@125	-13.0@3	-15.6@125	-1.4@29	-4.5@123	-5.1@122
	✓	✓			✓		✓		-9.8@116	-9.6@9	-7.5@122	3.0@96	11.2@123	4.5@121
									-14.8@127	-17.8@127	-13.1@8.2	-8.0@123	-1.1@112	-1@112
✓			✓		✓		✓		-8.5@116	-8.4@116	-8.7@116	4.3@123	1.2@19	1.2@19
									-14.1@125	-12.4@125	-15.7@125	-1.4@29	-4.5@123	-5.1@123
	✓		✓		✓		✓		-9.4@116	-9.2@116	-9.6@116	2.7@24	4.8@123	4.5@123
									-13.8@125	-15.3@125	-13.9@9	-3.7@23	-0.4@112	-0.4@112
✓		✓		✓			✓		-9.1@116	-8.9@116	-9.3@116	4.4@123	1.0@99	1.0@99
									-13.8@125	-12.3@4	-15.5@125	-0.9@28	-4.5@122	-4.5@122
	✓	✓		✓			✓		-8.4@116	-8.1@116	-8.6@116	2.4@25	5.6@123	4.5@123
									-13.9@125	-15.5@125	-13.0@8	-3.6@123	-4.2@3	-4.2@3
✓			✓	✓			✓		-9.8@116	-7.9@122	-9.6@30	8.0@123	1.5@31	1.5@31
									-15.1@127	-12.1@28	-20.1@127	-2.0@29	-4.5@121	-10.7@123
	✓		✓	✓			✓		-8.4@116	-9.4@116	-7.4@116	3.9@48	5.4@122	4.5@123
									-13.9@125	-15.5@125	-14.8@9	-4.6@122	-1.5@59	-1.5@59

NO WIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	SSME DEFLECTION MAXIMUM VALUES DURING BOOST (0 - 127 SEC)					
L	R	L	R	L	R	YES	NO		#1 PITCH	#2 PITCH	#3 PITCH	#1 YAW	#2 YAW	#3 YAW
✓		✓			✓		✓	0.1	-8.8@116 -15.0@59	-7.7@116 -15.9@59	-10.0@116 -16.0@125	4.8@123 -2.0@59	2.4@59 -4.5@123	2.4@59 -5.1@122
	✓	✓			✓		✓		-10.4@116 -15.0@127	-9.9@9 -20.0@127	-8.5@122 -14.1@59	3.0@9 -8.0@123	11.5@124 -1.0@9	4.5@121 -1.0@9
✓			✓		✓		✓		-9.0@116 -15.0@59	-9.0@116 -13.7@59	-9.1@116 -16.3@59	3.9@123 -1.0@28	1.6@59 -4.5@123	1.6@59 -5.1@123
	✓		✓		✓		✓		-10.0@116 -15.0@59	-9.8@116 -15.6@125	-10.2@116 -16.1@59	2.5@8.4 -3.4@123	4.8@123 -0.8@18	4.5@123 -0.8@18
✓		✓		✓			✓		-9.7@116 -14.5@59	-9.7@116 -14.2@59	-9.8@116 -15.8@125	3.9@123 -1.0@28	0.8@99 -4.5@123	0.8@99 -4.6@123
	✓	✓		✓			✓		-8.9@116 -14.6@59	-8.7@116 -15.9@125	-9.2@116 -14.7@59	2.2@8 -3.4@124	5.5@123 -1.0@11	4.5@123 -1.0@17
✓			✓	✓			✓		-10.4@116 -15.5@59	-8.4@122 -12.9@59	-10.1@29 -20.2@127	8.0@123 -1.8@29	1.1@112 -4.5@121	1.1@112 -1.1@123
	✓		✓	✓			✓		-8.9@116 -15.5@59	-9.9@116 -15.9@125	-8.0@116 -18.0@59	5.2@59 -4.4@123	5.4@123 -2.6@59	4.5@123 -2.6@59

TAILWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	SUME DEFLECTION MAXIMUM VALUES DURING BOOST (0 - 127 SEC)					
L	R	L	R	L	R	YES	NO		#1 PITCH	#2 PITCH	#3 PITCH	#1 YAW	#2 YAW	#3 YAW
✓		✓			✓		✓	0.1	-8.1@116	-6.7@116	-9.4@116	5.4@122	1.3@31	1.3@31
									-13.6@125	-13.3@3	-15.4@125	-2.0@29	-4.5@123	-5.1@122
	✓	✓			✓		✓		-9.7@116	-9.1@26	-7.7@122	3.7@26	10.9@123	4.5@122
									-14.7@127	-19.7@127	-13.3@8	-8.0@123	-1.2@112	-1.2@112
✓			✓		✓		✓		-8.4@116	-8.2@116	-8.6@116	4.7@123	1.5@19	1.5@19
									-13.9@126	-12.5@30	-15.6@125	-2.9@30	-4.5@123	-5.0@122
	✓	✓	✓		✓		✓		-9.2@116	-9.1@116	-9.4@116	3.8@23	4.8@123	4.5@123
									-13.6@125	-15.0@125	-14.7@20.1	-3.8@123	-0.4@30	-0.4@30
✓		✓		✓			✓		-8.9@116	-8.6@116	-9.2@116	4.6@123	1.3@23	1.3@23
									-13.6@125	-12.5@6	-15.3@125	-2.2@29	-4.4@122	-4.4@122
	✓	✓		✓			✓		-8.2@116	-7.9@116	-8.5@116	3.4@23	5.7@123	4.5@123
									-13.6@125	-15.3@125	-13.2@8	-3.8@123	-0.5@3	-0.5@3
✓			✓	✓			✓		-9.6@116	-7.6@122	-8.8@31	8.0@123	2.2@31	2.2@31
									-15.1@127	-12.7@30	-20.1@127	-3.3@30	-4.5@121	-10.2@123
	✓		✓	✓			✓		-8.2@116	-9.2@116	-7.2@116	4.7@26	5.5@122	4.5@122
									13.7@125	-15.2@125	-15.3@9	-4.7@122	-1.7@62	-1.7@62

HEADWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	NOZZLE DEFLECTION MAXIMUM VALUES DURING BOOST (0 - 127 SEC)					
L	R	L	R	L	R	YES	NO		#1 PITCH	#2 PITCH	#3 PITCH	#1 YAW	#2 YAW	#3 YAW
✓		✓			✓		✓	57	-8.2@116	-6.5@116	-9.9@116	6.4@58	2.0@60	2.0@60
									-14.0@126	-13.1@127	-15.9@125	-0.3@28	-4.5@123	-4.7@122
	✓	✓			✓		✓		-9.8@116	-8.5@97	-8.0@122	6.5@58	11.5@123	4.5@121
									-14.3@127	-19.2@127	-15.1@58	-8.0@123	-1.0@112	-1.0@112
✓			✓		✓		✓		-8.8@116	-8.2@116	-9.3@116	7.7@58	3.6@59	3.6@59
									-14.2@126	-13.1@127	-17.5@59	-0.3@28	-4.5@123	-4.6@122
	✓		✓		✓		✓		-9.7@116	-9.1@116	-10.3@116	7.3@58	5.2@123	4.5@123
									-13.9@126	-15.0@125	-17.2@58	-2.9@123	-4.3@26	-4.3@26
✓		✓		✓			✓		-8.9@116	-8.3@116	-9.6@116	6.3@58	2.2@59	2.2@59
									-13.9@126	-12.8@127	-15.8@125	-0.3@28	-4.1@122	-4.1@122
	✓	✓		✓			✓		-8.2@116	-7.5@116	-9.0@116	6.0@58	6.3@123	4.5@122
									-13.7@125	-15.2@125	-14.9@58	-3.1@124	-4.3@26	-4.3@26
✓			✓	✓			✓		-9.8@116	-7.7@122	-10.4@113	8.0@122	1.5@107	1.5@107
									-15.8@127	-12.0@6	-20.5@127	-1.1@112	-4.5@121	-10.0@123
	✓		✓	✓			✓		-8.4@116	-8.7@58	-7.8@116	8.0@59	5.8@123	4.5@122
									-14.8@59	-15.2@125	-19.8@59	-3.8@123	-2.5@59	-2.5@59

RIGHT XWIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	SOME DEFLECTION MAXIMUM VALUES DURING BOOST (0 - 127 SEC)					
L	R	L	R	L	R	YES	NO		#1 PITCH	#2 PITCH	#3 PITCH	#1 YAW	#2 YAW	#3 YAW
✓		✓			✓		✓	28	-8.2@116 -14.1@126	-6.5@116 -13.1@127	-9.9@116 -15.9@125	6.7@58 -4.6@29	2.0@60 -4.5@123	2.0@60 -4.7@122
	✓	✓			✓		✓		-9.9@116 -14.3@127	-8.4@58 -19.2@127	-8.1@122 -15.2@58	6.8@58 -8.0@123	11.5@123 -1.0@112	4.5@121 -1.0@112
✓			✓		✓		✓		-8.9@116 -14.3@126	-8.3@116 -13.1@127	-9.4@116 -17.4@58	7.7@58 -0.2@28	3.2@59 -4.5@123	3.2@59 -4.6@122
	✓		✓		✓		✓		-9.7@116 -14.0@126	-9.1@116 -15.1@125	-10.4@116 -17.1@58	7.2@58 -2.8@123	5.2@123 -0.4@26	4.5@123 -0.4@26
✓		✓		✓			✓		-8.9@116 -13.9@127	-8.2@116 -12.8@127	-9.6@116 -15.8@125	6.3@58 -0.2@28	2.2@59 -4.1@122	2.2@59 -4.1@122
	✓	✓		✓			✓		-8.2@116 -13.7@125	-7.5@116 -15.2@125	-8.9@116 -14.9@58	5.9@58 -3.1@124	6.3@123 -0.4@26	4.5@122 -0.4@26
✓			✓	✓			✓		-9.9@116 -15.8@127	-7.8@122 -12.0@6	-10.4@113 -20.5@127	8.0@122 -1.2@112	1.4@112 -4.5@121	1.4@112 -10.1@123
	✓		✓	✓			✓		-8.5@116 -15.0@59	-8.9@58 -15.2@125	-7.8@116 -20.0@59	8.0@58 -3.9@123	5.8@123 -2.8@58	4.5@122 -2.8@58

RIGHT X WIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	BOOSTER DEFLECTION MAXIMUM VALUES DURING BOOST (0 - 127 SEC)					
L	R	L	R	L	R	YES	NO		#1 PITCH	#2 PITCH	#3 PITCH	#1 YAW	#2 YAW	#3 YAW
✓		✓			✓		✓	8	-8.2@116	-6.5@116	-9.9@116	6.7@58	2.0@60	2.0@60
									-14.0@126	-13.1@127	-15.9@125	-6.8@29	-4.5@123	-4.7@122
	✓	✓			✓		✓		-9.8@116	-8.4@58	-8.0@122	6.7@58	11.5@123	4.5@121
									-14.3@127	-19.2@127	-15.2@58	-8.0@123	-1.0@26	-1.0@26
✓			✓		✓		✓		-8.8@116	-8.2@116	-9.4@116	7.9@58	3.3@59	3.3@59
									-14.2@126	-13.1@127	-17.5@58	-1.0@29	-4.5@123	-4.5@123
	✓		✓		✓		✓		-9.7@116	-9.1@116	-10.4@116	7.4@58	5.2@123	4.5@123
									-13.9@126	-15.0@125	-17.1@58	-2.8@123	-0.2@8	-0.2@8
✓		✓		✓			✓		-8.9@116	-8.2@116	-9.6@116	6.2@58	2.2@59	2.2@59
									-13.9@127	-12.8@127	-15.8@125	-5.3@28	-4.1@122	-4.1@122
	✓	✓		✓			✓		-8.2@116	-7.5@116	-8.9@116	5.9@58	6.3@123	4.5@122
									-13.7@125	-15.1@125	-14.9@58	-3.1@124	-4.3@18	-4.[illegible]@18
✓			✓	✓			✓		DATA LOST					
	✓		✓	✓			✓		DATA LOST					

RIGHT X WIND

SRM W/ HIGH THRUST		SRM W/ FAILED ACT.		ACT. FAILED		FAIL MODE LOGIC		TIME OF ACT. FAIL (SEC)	SOME DEFLECTION MAXIMUM VALUES DURING BOOST (0 – 127 SEC)					
L	R	L	R	L	R	YES	NO		#1 PITCH	#2 PITCH	#3 PITCH	#1 YAW	#2 YAW	#3 YAW
✓		✓			✓		✓	0.1	-8.2@116 -14.0@126	-6.5@116 -13.1@127	-9.9@116 -15.9@125	6.6@58 -1.1@3	2.0@60 -4.5@123	2.0@60 -4.7@122
	✓	✓			✓		✓	0.1	-9.8@116 -14.3@127	-8.4@58 -19.2@127	-8.0@122 -15.2@58	6.7@58 -8.0@123	11.5@123 -1.0@26	4.5@121 -1.0@26
✓			✓		✓		✓	0.1	-9.7@116 -13.9@125	-9.1@116 -15.0@125	-10.4@116 -17.1@58	7.4@58 -2.8@123	5.2@123 -0.1@1.2	4.5@123 -0.1@1.2
	✓		✓		✓		✓	0.1	-8.9@116 -13.9@127	-8.1@116 -12.8@127	-9.6@116 -15.8@125	6.2@58 -0.5@28	2.2@59 -4.1@122	2.2@59 -4.1@122
✓		✓		✓			✓	0.1	NO DATA					
	✓	✓		✓			✓	0.1	-9.9@116 -15.8@127	-7.8@122 -12.0@6	-10.1@30 -20.5@127	8.0@122 -1.4@29	1.5@31 -4.5@121	1.5@31 -10.1@123
✓			✓	✓			✓	0.1	NO DATA					
	✓		✓	✓			✓	0.1	NO DATA					

RIGHT X WIND

APPENDIX B2

INDIVIDUAL ACTUATOR DUTY CYCLE DATA

NO ACT. FAILURES
BASELINE SYST.

WIND	THRUST MIS-MATCH	DUTY CYCLE			
		L MTR L ACT	R MTR L ACT	L MTR R ACT	R MTR R ACT
RIGHT CROSS	+	15.6	26.0	23.1	17.4
RIGHT CROSS	−	16.2	24.6	23.8	19.4
HEAD	+	16.2	21.8	20.8	15.9
HEAD	−	15.7	21.2	21.6	17.0
TAIL	+	16.9	22.0	21.1	16.7
TAIL	−	15.4	21.4	22.1	18.9
NONE	+	13.9	19.8	18.6	13.5
NONE	−	13.0	19.1	19.6	15.2

+ = L MTR W/ "HOT" BURN
− = R MTR W/ "HOT" BURN

BASELINE SYSTEM
L ACT ON R MTR
FAILED AT
0.1 SEC
NO COMP LOGIC

WIND	THRUST MIS-MATCH	DUTY CYCLE			
		L MTR L ACT	R MTR L ACT	L MTR R ACT	R MTR R ACT
RIGHT CROSS	+	29.0	0.3	30.7	28.8
RIGHT CROSS	−	27.1		32.0	28.6
HEAD	+	26.9		24.6	24.8
HEAD	−	24.1		25.1	23.1
TAIL	+	25.0		22.5	22.5
TAIL	−	21.3		21.8	23.4
NONE	+	21.5		20.5	20.8
NONE	−	19.5		20.9	20.6

+ = L MTR W/ "HOT" BURN
− = R MTR W/ "HOT" BURN

BASELINE SYSTEM
L ACT ON R MTR
FAILED AT 0.1 SEC
W/ COMP LOGIC

WIND	THRUST MIS-MATCH	DUTY CYCLE			
		L MTR L ACT	R MTR L ACT	L MTR R ACT	R MTR R ACT
RIGHT CROSS	+	32.5	0.3	34.2	32.4
RIGHT CROSS	−	29.3		37.4	30.4
HEAD	+	30.7		23.8	31.1
HEAD	−	27.1		25.0	29.3
TAIL	+	29.8		21.9	30.9
TAIL	−	26.6		22.8	28.4
NONE	+	26.0		22.0	26.0
NONE	−	22.5		23.0	24.0

+ = L MTR W/ "HOT" BURN
− = R MTR W/ "HOT" BURN

0°-90° SYSTEM
W/ COMP.

WIND	THRUST MIS-MATCH	DUTY CYCLE L MTR Y ACT	R MTR Y ACT	L MTR P ACT	R MTR P ACT	
RIGHT CROSS	+	14.6	14.6	0.4	28.5	fail Y act L mtr
	−	16.2	16.2	0.4	31.1	
	+	15.8	15.8	29.5	0.4	fail Y act R mtr
	−	15.6	15.6	32.1	0.4	
	+	0.0	21.0	22.5	26.9	fail P act L mtr
	−	0.0	23.0	24.2	25.7	
	+	21.4	0.0	22.4	27.0	fail P act R mtr
	−	22.1	0.0	23.3	25.1	

+ = L MTR W/ "HOT" TURN
− = R MTR W/ "HOT" TURN