



Ascent Flight Changes Due To SCR 93087 (RTLS ET Separation Improvements)

Ascent Flight Techniques Panel

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Mike Cagle
David Almanza
Raymond Haraway
Andrew Flottorp



◆ PURPOSE

- Review the ascent flight changes to RTLS ET Separation caused by SCR 93087

Background - Why Do We Need RTLS ET Separation Improvements?

- ◆ **RTLS is considered to be the riskiest of the intact abort scenarios**
- ◆ **The current RTLS ET Sep system design provides:**
 - **~84% + Monte-Carlo passing rate for the GPC failed condition with one sigma /one sided dispersion protection (w/no restringing of GPC)**
 - **Basically, when a GPC fails in the presence of large dispersions, the remaining 7 -Z jets are insufficient to perform the -Z translation while simultaneously controlling the roll and pitch axes.**
 - This causes the number of down firing RCS jets available to be downmoded to 6.
 - **~97% + passing rate for the no GPC failed scenario with one sigma systems dispersions**
- ◆ **Flight software SCR 93087 reduces RTLS intact abort risk by decreasing the ET separation maneuver failure rate during RTLS intact aborts with dispersions and GPC failures by 30 to 60%**

Background - What is a RTLS ET Separation Failure?

- ◆ **All RTLS ET separation failures are classified into four categories:**
 1. Near field/umbilical plate recontacts – failure to cleanly separate
 2. Far field re-contacts – Orbiter/Tank separate and later re-contact
 3. Roll axis loss of control (with jet failures)– current roll channel design uses up and down firing aft jets to control roll, but the same jets are also used for pitch control and the –Z burn, leaving minimal control authority for roll control
 4. Pitch axis loss of control (with jet failures)– current pitch channel design provides insufficient pitch control authority to reach necessary pitch attitudes and rates. When roll control is invoked, pitch control is further compromised.

- ◆ **SCR 93087 addresses these failures through the application of:**
 - New mated coast GN&C powered pitch down logic
 - New RCS jet application logic
 - The early deployment of the rudder/speed brake to improve pitch trim

Flight Software/Design Changes in SCR 93087

- ◆ **Near Field Recontact Scenarios - No software change was identified to alleviate the near field umbilical plate recontacts**
 - Typically about 20% of the failure cases fall into this category with most showing about one tenth of an inch violation

- ◆ **Far Field Recontact (FFR) Scenarios - A pitch-down maneuver at the end of mated coast is proposed that will command the mated vehicle to pitch from alpha 0 deg to alpha -2.8 deg at a rate of -0.8 deg/sec**
 - Alpha MECO target will be changed from the current -2 degrees to 0 degrees.
 - The average pitch rate at separation increase from -.25 deg/sec to -.8 deg/sec to help ensure that the ET does not pitch up towards Orbiter after separation

- ◆ **Roll Loss of Control (LOC) Scenarios – Applies to cases with jet failures (GPC down)**
 - Yaw jets, when not used for yaw control, are used to supplement roll control
 - For low Qbar (<7.5 psf), no roll control during the open loop portion of ET Separation
 - At MM602 (end of ET Separation), roll error limit (entry requirement) is ± 30 degrees.
 - The roll attitude error signal was modified to enhance recovery when the vehicle is severely rolled off and to minimize interference with -Z burn
 - Added a roll attitude deadband of 4 degrees during ET Separation
 - Currently, there is no deadband so as soon as a roll error of 1/2 degree is reached, down firing jets are turned off which leads to a loss of some -Z and pitch control
 - For large roll-offs, the roll attitude restoring rate was increased from 1 deg/sec to 5 deg/sec
 - Consistent with entry limit of 5 deg/sec

Flight Software/Design Changes in SCR 93087 (continued)

◆ Pitch Loss of Control (LOC) – during ET Separation with -Z jet failed

- PITCH_ERRT, the difference between actual and desired pitch attitude, is a redline used to:
 - 1) Override the open loop timer (3 sec open loop burn) if the redline limits for the pitch error signal are exceeded, resulting in the aft -Z jets being toggled off/on as needed to regain pitch control (Basically an early closing of the pitch channel)
 - 2) After the open loop timer expires, fire one additional +Z jet to aid in pitching the vehicle up if the redline limit is exceeded.
- At MECO_CONFIRMED, the Rudder/Speed brake is deployed at the maximum rate until it reaches 80.6 degrees, to increase the aerodynamic pitching moment.
 - The 80.6 degrees matches the current entry value of speed brake deployment when Q_{bar} is ≥ 20 psf

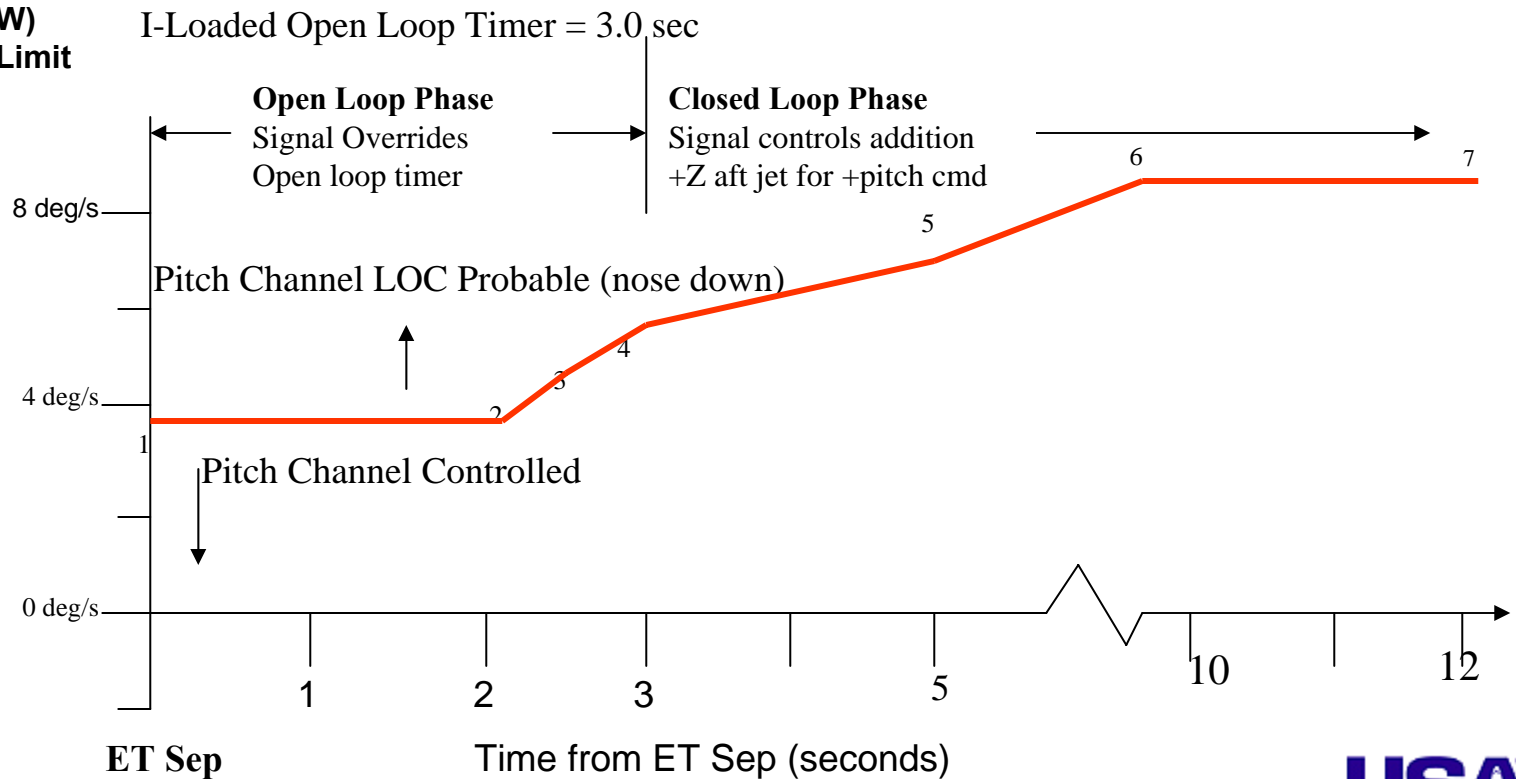
ET Separation Pitch Channel Enhancements

- ◆ Pitch channel open loop timer override closes pitch loop when the new redline limit is reached
 - +Z aft jets are added to the UY=3/UX= ±3 commands to increase the positive pitch control after Loop is closed
 - A positive value means the vehicle's pitch attitude is below the desired pitch attitude determined in GC_STEER and the vehicle needs to pitch up

Pitch Error Signal (NEW)
PITCH_ERRT Redline Limit

Table of Points

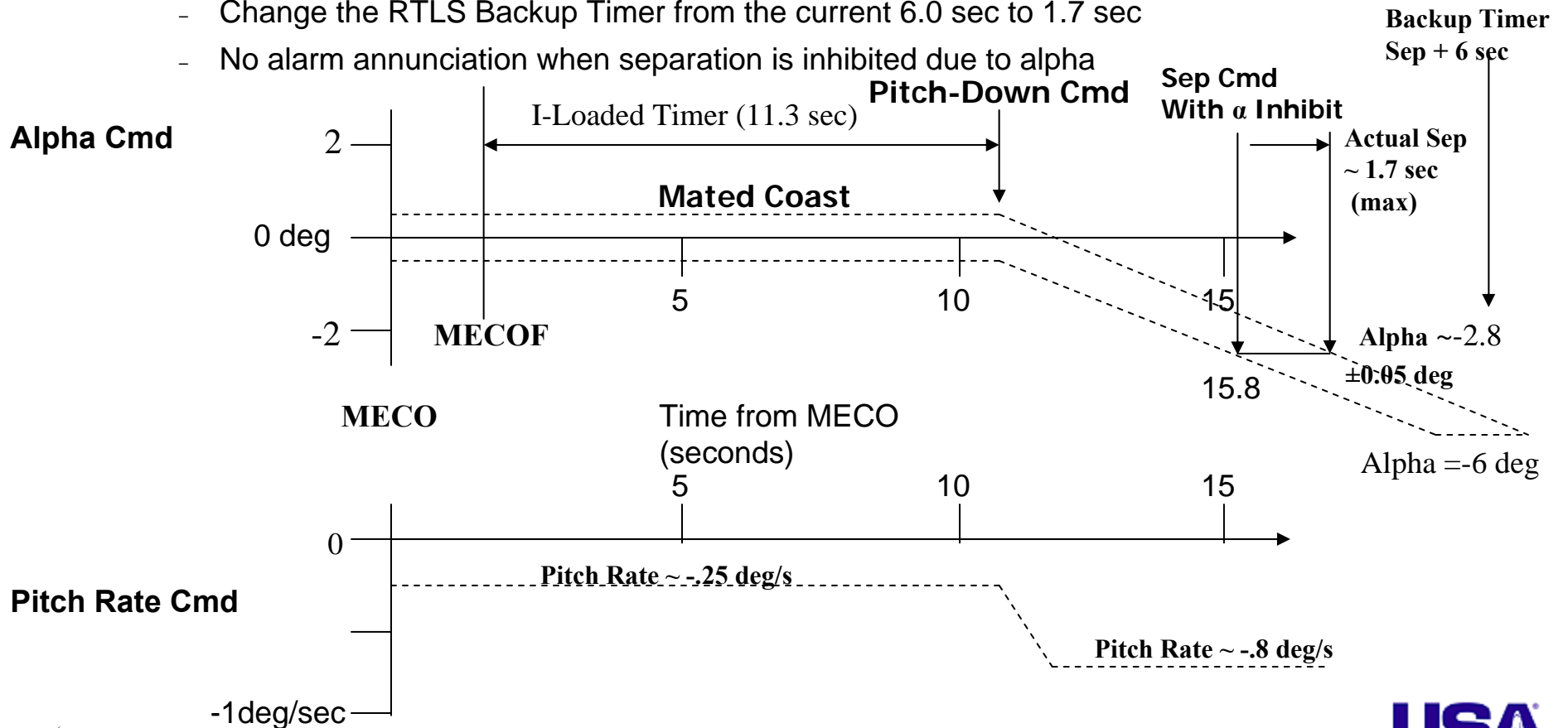
- 1 = 3.8
- 2 = 3.8
- 3 = 5.0
- 4 = 6.0
- 5 = 7.0
- 6 = 8.0
- 7 = 8.0



Modified Alpha Profile for ET Separation

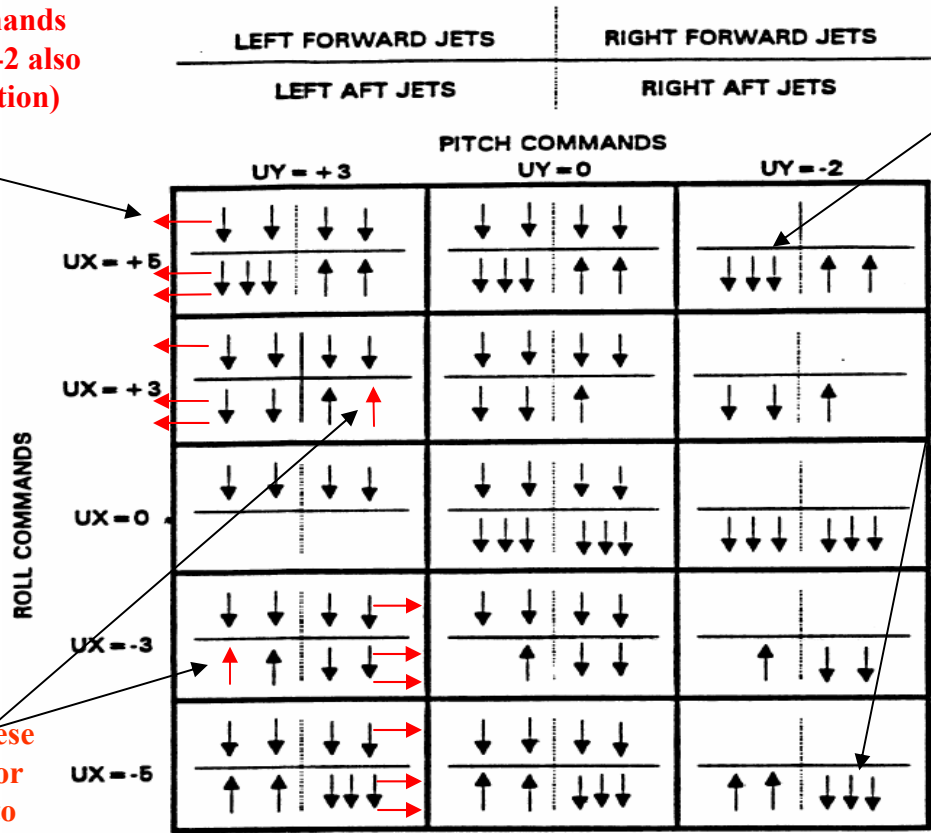
◆ **Separating with the Alpha inhibit active reduces dispersions to bare minimum**

- Change the powered RTLS MECO Alpha target from -2.0 deg to 0.0 deg
- Dispersions in Alpha are traded for variations in the time of ET Sep (~1.7 sec)
- Separation Very Insensitive to the effects of an ~1.7 sec delay
- Change the RTLS Backup Timer from the current 6.0 sec to 1.7 sec
- No alarm annunciation when separation is inhibited due to alpha

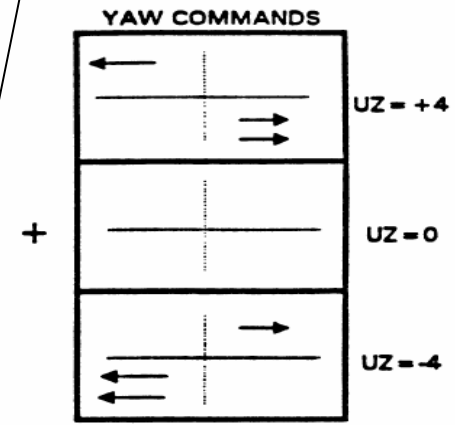


RTLS ET Separation RCS Jet Changes

Enhanced RCS Roll Commands
 Typical for $UY=0$ & $UY = -2$ also
 (New RCS Aero Configuration)



High level roll command down-
 modes to low level mode when
 one of three -Z jets has failed
 (RCS Aero not impacted)



One +Z aft jet added to these
 commands when pitch error
 signal redline is exceeded to
 maximize + pitch command
 (Correction to existing RCS
 Configuration Required)

Modeling of Speed Brake Use

- ◆ **Deployment of the Speed Brake Aero during Mated Coast**
 - **Starts at MECO CONFIRMED and is deployed at the maximum rate of 6.1 deg/sec until 80.6 deg is reached. The 80.6 deg is the setting that Entry currently opens the speed brake to when $Q_{bar} \geq 20$ psf is reached**
 - **Increases positive pitch moment on the vehicle after ET separation**

Recommendation

- ◆ **Give approval for the implementation of the RTLS ET Separation Enhancements into OI-33.**

Backup Data

RTLS ET Separation Improvements Study Concept Validation

- ◆ **RTLS ET separation Monte-Carlo analysis is used to validate the proposed changes**
 - **Standard verification matrix consists of 300 ETSEP simulation test cases with random SSME failures and failure times and one sigma system dispersions**
 - **Standard matrix is also run with random GPC failures to provide worst case environment for the FCS**
- ◆ **The proposed changes were run individually with inputs set at different values to verify their efficacy**
- ◆ **Final changes were run in combination to prove compatibility**
- ◆ **Three scenarios were run for validation**
 - **STS-121 – Typical Space Station mission**
 - **STS-107 – Heavy weight orbiter, heavy weight tank – severe case for control**
 - **PE Certification Matrix – Greatest variation of conditions**

RTLS Design Staging Conditions

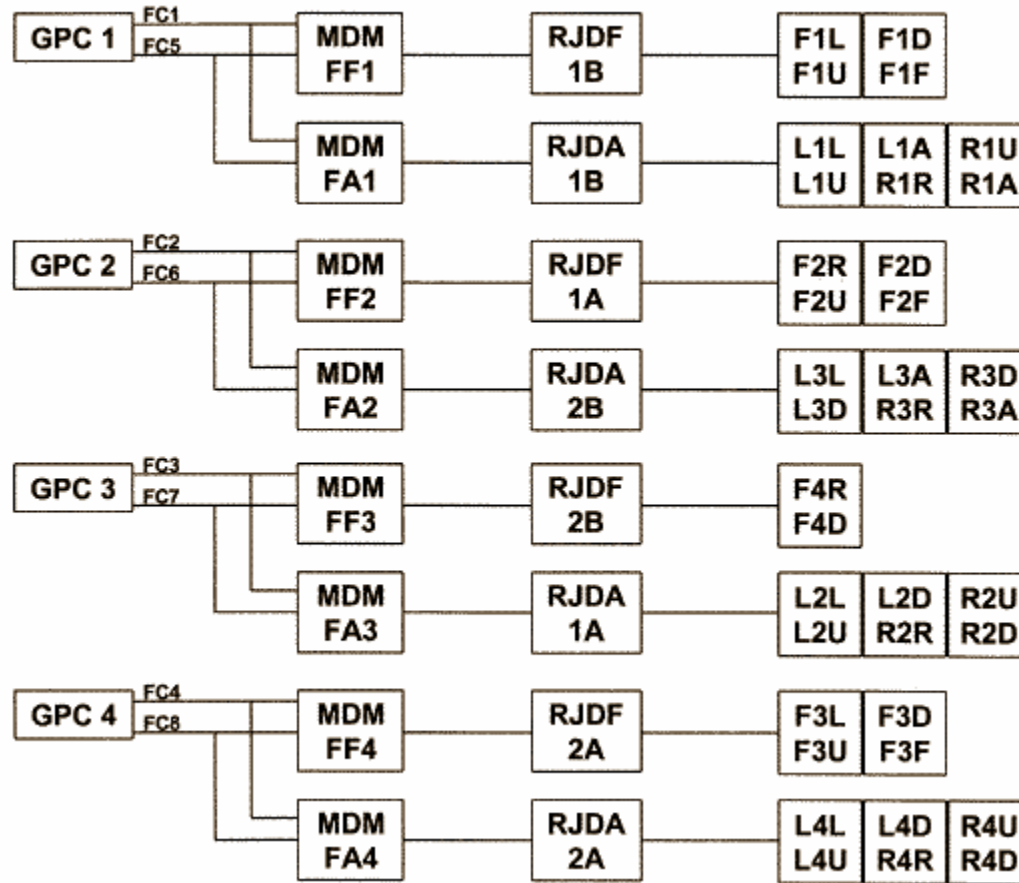
Parameter/Event	MECO	Structure Release	MM602-Separation Termination
Angle of Attack – Deg	-3.0 ± 1.5	-2.5 ± 1	≥ 10
Roll Angle – Deg	0 ± 2	0 ± 20	0 ± 30
Sideslip Angle – Deg	0 ± 2	0 ± 2.0	0 ± 3
Yaw Rate – Deg/Sec	$0 \pm .5$	$0 \pm .5$	0 ± 1
Roll Rate – Deg/Sec	$0 \pm .5$	0 ± 2	0 ± 2
Pitch Rate – Deg/Sec	$-.25 \pm .5$	$-.25 \pm .5^2$	2.5 ± 2.5
Dynamic Pressure ¹ (lb/ft ²)		$6 \leq q \leq 9.5$	

1) DYNAMIC PRESSURE

The undispersed engine-out ET structural release Qbar target zone of 6 to 9.5 psf is based on range reference atmosphere. These dynamic pressure limits represent the undispersed engine-out variation target zone to which the RTLS ET sep Qbar designs were assessed and must adhere. Details on the application of these limits to the I-Load design process are presented in NSTS 08209, Volume IV, Shuttle Systems Design Criteria, Design Criteria and Constraints, Paragraph 3.3.2.3, RTLS ET Separation Conditions. Dynamic pressure limits are based on simulated environments (not flight software derived). Limits for all the other parameters (alpha, beta, roll and body rates) are flight software derived.

2) Pitch Rate limit at Structure Release will have to be changed in NSTS 07700 Volume X, Book 1, Section 3.2.1.1.10.2.2 Orbiter/ET Abort Separation Performance (RTLS) detailed in Figure 3.2.1.1.10.2.4.

RCS Jet Channelization – Nominal Configuration



STS-121 ET Sep Monte Carlo Results

- ◆ **NSTS-07700 Vol. X criteria for RTLS ET Separation: at least 1σ protection (84% of the cases must perform the separation maneuver successfully) with a GPC Failure**

FAILURE MODE	NUMBER OF FAILURES STS-121			
	BASELINE	PROPOSED S/W CHANGES	BASELINE W/ NO GPC FAILURES	PROPOSED S/W CHANGES W/ NO GPC FAILURES
LOC Only	22	16	0	0
NFR Only	9	6	0	1
FFR Only	0	0	0	0
MCV	0	0	0	0
Total Failures	31	22	0	1
Total Cases	300	300	300	300
Passing Rate	89.67%	92.67%	100.0%	99.67%

STS-107 ET Sep Monte Carlo Results

- ◆ **NSTS-07700 Vol. X criteria for RTLS ET Separation: at least 1s protection (84% of the cases must perform the separation maneuver successfully) with a GPC Failure**
- ◆ **With the implementation of the proposed enhancements only two cases had roll violations at MM602 and there were no FFR/MCV**

FAILURE MODE	NUMBER OF FAILURES STS-107			
	BASELINE	PROPOSED S/W CHANGES	BASELINE W/ NO GPC FAILURES	PROPOSED S/W CHANGES W/ NO GPC FAILURES
LOC Only	25	2	0	0
NFR Only	8	12	3	3
FFR Only	2	0	5	0
MCV	1	0	6	0
Total Failures	36	14	14	3
Total Cases	300	300	300	300
Passing Rate	88.0%	95.3%	95.3%	99.0%

PE ET Sep Monte Carlo Results

- ◆ **NSTS-07700 Vol. X criteria for RTLS ET Separation: at least 1s protection (84% of the cases must perform the separation maneuver successfully) with a GPC Failure**

FAILURE MODE	NUMBER OF FAILURES PE Certification			
	BASELINE	PROPOSED S/W CHANGES	BASELINE W/ NO GPC FAILURES	PROPOSED S/W CHANGES W/ NO GPC FAILURES
LOC Only	27	8	0	0
NFR Only	6	4	9	3
FFR Only	3	0	7	0
MCV	3	0	4	1
Total Failures	39	12	20	4
Total Cases	300	300	300	300
Passing Rate	87.0%	96.0%	93.33%	98.67%

STS-121 MM 602 Transition Roll and Roll Rate Vol. X Violations (Includes random GPC Failures)

The remaining failure cases, with one exception, are moving in a direction favorable for recovery.

