Volume V
Appendix G.6

SRB Working Group Presentation to CAIB

This Appendix contains the SRB Working Group Presentation to Columbia Accident Investigation Board, 28 May 2003.

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SRB Working Group Presentation to Columbia Accident Investigation Board CAIB.pdf

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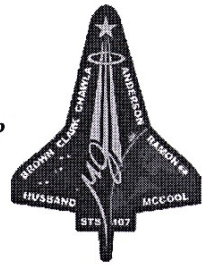
Solid Rocket Booster Working Group Agenda

SRB Working Group



- Executive Summary
- **List of Members, Advisors, Observers, and Others**
- Method of Investigation
  - Special Circumstances
  - Investigation Process
- Fault Tree Closure Summary
- Summary

Note: The symbol ▣ indicates a link to back up information.

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Solid Rocket Booster Working Group Team Members

SRB Working Group

SRB Working Group (NASA Team)

Darrell Davis	Thermal
Joe B. Davis	Pyrotechnics
Jeff Dilg	Structures
Don Ford	Systems Engineering
Joe Gentry	Structures
Rusty Jones	Loads/Environments
Joe Lusk	SRBWG Deputy Chair and Assistant Project Manager, SRB Project Office
Tina Malone	M&P
Malissa Meadows	E&I
Boris Pagan	TVC
Tom Reickhoff	Photo Analysis
Pete Rodriguez	SRBWG Chair and Deputy Manager, Structures, Mechanics and Thermal Department
George Story	BSM
Randall Tucker	S&MA
Renee Wilson	SRBWG Secretary

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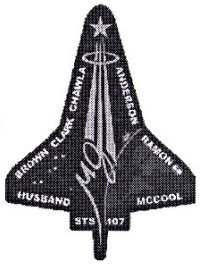
Other Key Players

SRB Working Group



Review and Assessment

Peggy Frazier
Chantel Jacob
Mike Norris

Systems Fault Tree Review Team

Joe Brunty
Dan Mullane
Richard Sheppard
John Townsend

DCMA Key Players

Jim Anderson
Craig Bennett
Myles Campbell
Primo Correa
Carlos de Mattos
Joe Giedlinski
Robert Kaufmann
Robert Kauffman
Dave Kedell
Ron Koehn
Norm Powers
Tom Root
Mike Smutek
Terence Young

NASA S&MA MSFC and KSC

Foster Anthony
Shane Canerday
Neal Hooten
Art Morales
Robert Osterblum
Rick Sizemore

NASA MSFC SRB Resident Office at KSC

Homero Hidalgo
Tom Engler
Robin Ferebee
Sandy Norris

SRBWG Senior Advisory Group

Vince Caruso(retired), Former Manager, Systems Management and Integration Office, Space Shuttle Main Engine
Keith Coates(retired), Former Chief Engineer, Solid Rocket Motor Program
Erich Engler(retired), Former Chief, Structural Development Branch, Science and Engineering Directorate
Bob Henry(retired), Former Senior Technical Assistant to the Chief Engineer, Solid Rocket Booster Program
Bill Horton(retired), Former Chief Engineer, Solid Rocket Booster Program

Senior Independent Review

Moody Davis(retired), Former Manager, Testing and Operations Office, Chief Engineer's Office, Solid Rocket Motor Program
Jim Thomas(retired), Former Manager, Technical Operations Office, Solid Rocket Motor Program

Fault Tree Independent Review

Robert Schwinghamer(retired), former Assistant Center Director - Technical, MSFC

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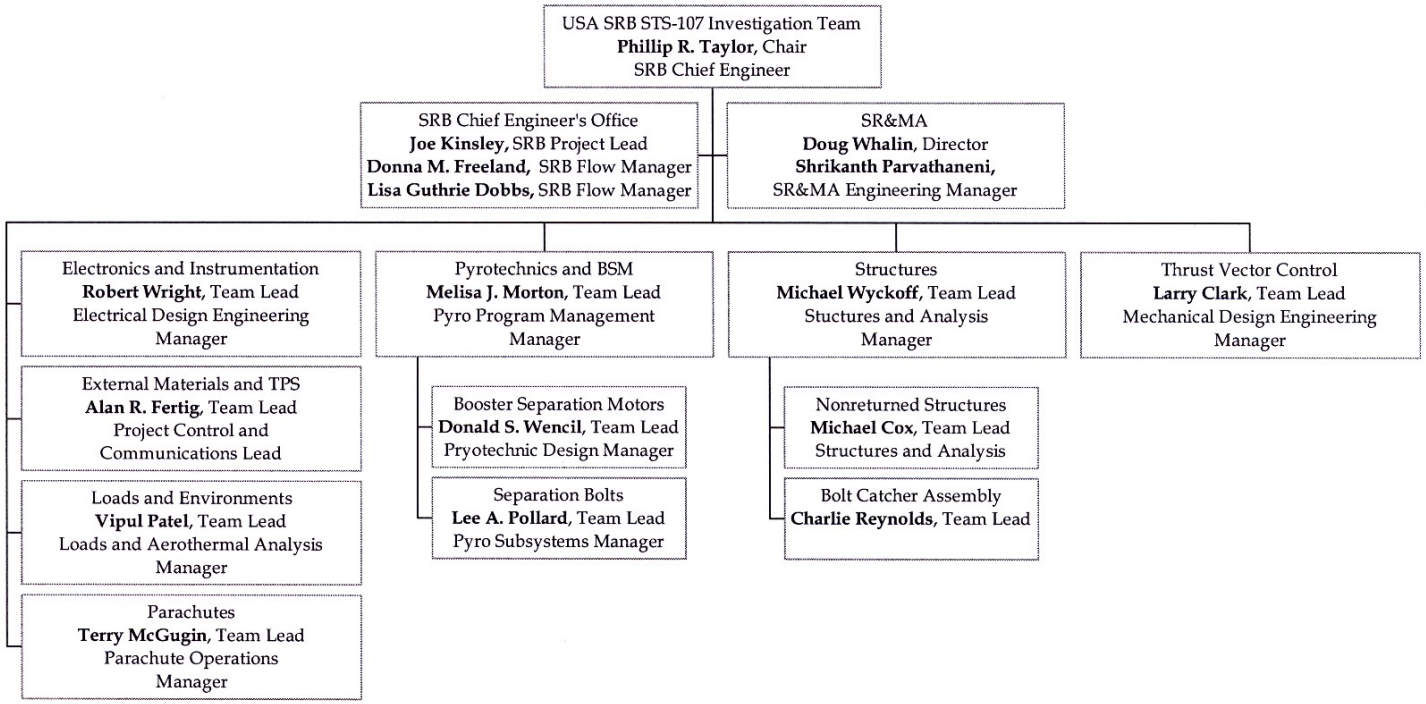
Solid Rocket Booster Working Group Team Members

SRB Working Group

USA Investigation Team Leads/Key Players



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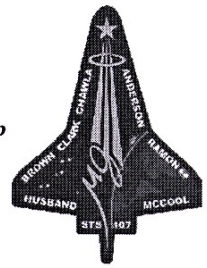
Solid Rocket Booster Working Group Agenda

SRB Working Group



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Special Circumstances

SRB Working Group

- **Hardware Status As of February 1, 2003:**
  - Open Assessment of STS-107 SRB/RSRM Hardware Completed on 1/20/03
  - The SRB/RSRM Disassembly Schedule Was Nearly Complete
  - Refurbishment Was in Work
  - USA Post Flight Assessment Team Performed Initial Thorough Assessment of Hardware
  - SRBWG Reviewed Post Flight Data and Photography plus Hardware as it was in the Disassembly and Refurbishment Process

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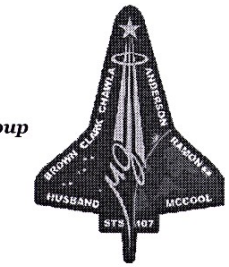
Solid Rocket Booster Working Group Agenda

SRB Working Group



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SRB Working Group Presentation to Columbia Accident Investigation Board CAIB.pdf
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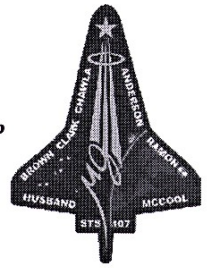
Investigation Process

SRB Working Group



SRB Hardware classified into two categories

- **Retrieved Hardware**
  - Post-Flight Assessment
  - SRBWG Re-Assessment
  - Video and Photography
  - Flight Loads Analysis/Flight Data
  - 10MNL-0035 Requirements Document
- **Non-Retrieved Hardware**
  - Video and Photography
  - Comparison to Retrieved Hardware with Equal Processing
  - Flight Data (DAS, Telemetry)
  - Documentation Assessment Including:
    - As-designed vs. As-Built
    - Engineering Changes Affecting STS107
    - Problem Reports/Squawks/Non-Conformances
    - SRB Build-up and Consumables
    - Ground Operations Build-up Documents
    - NASA ALERTS
    - Hazard Analysis and CIL Correlation
    - SRB Waiver List Review

SRBWG Philosophy: "All Hardware is Guilty until Proven Innocent." John Key

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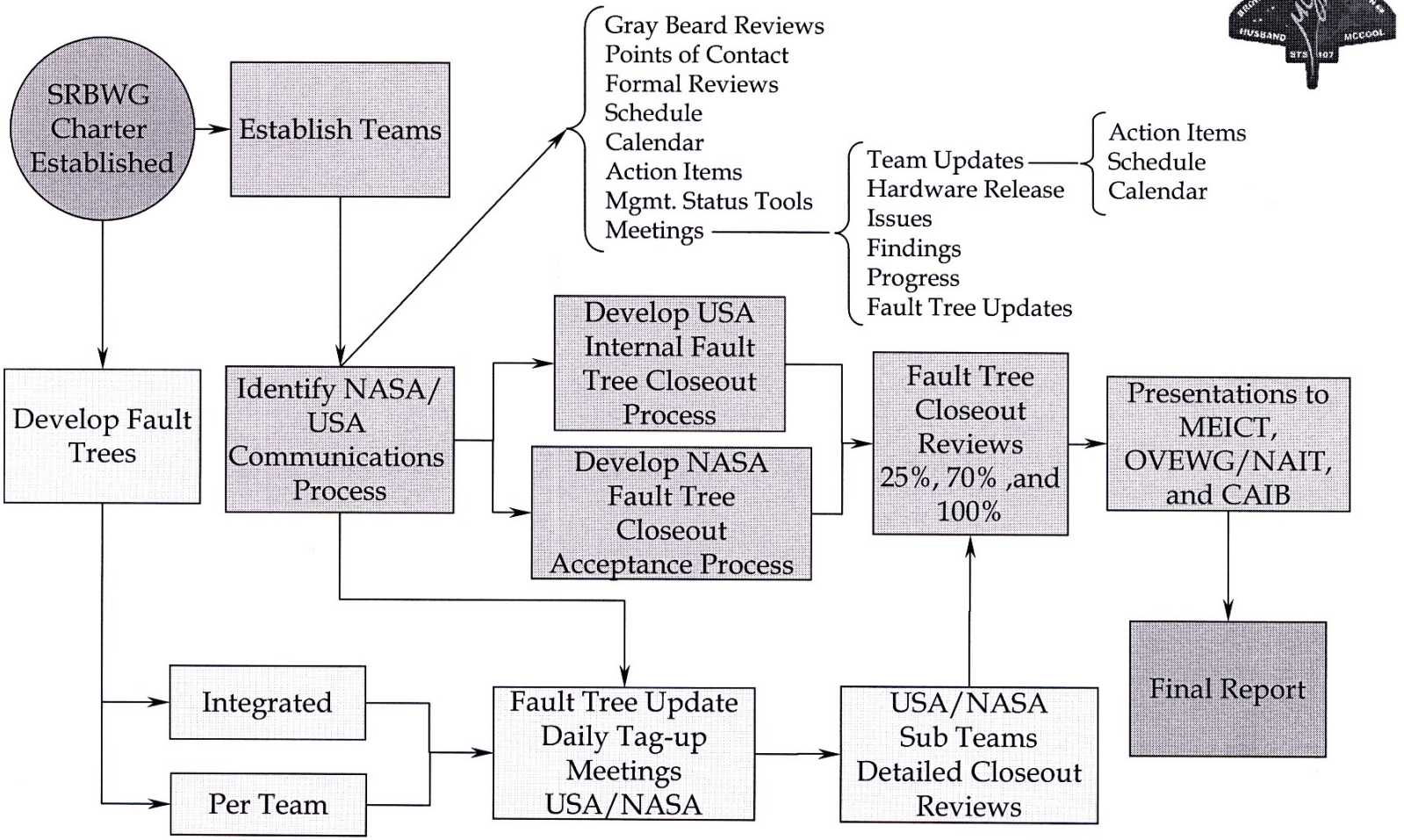
Investigation Process

SRB Working Group



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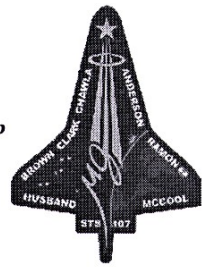
Investigation Process

SRB Working Group



Operational Experience and Design Limits

- Knowledge of both existing data base and design limits (overall and second-by-second) needed to understand hardware performance
- Each Shuttle flight adds to our knowledge and experience base
- Deviations/Exceedances from the experience base result in executing planned activities to understand the "what", "how" and "why" of event.

Fault Tree Development

- Fault Tree developed and checked against Hazards Analysis and Critical Items List (CIL)

Independent Reviews

- Senior Advisory Group
  - 2 Reviews for Fault Tree Development
  - 3 Reviews for Closure Development
  - 2 Final Presentation Reviews
- MSFC Systems Team – 1 Fault Tree Development Review

SRBWG Fault Tree mapped to MEIC/Systems and CAIB Fault Tree

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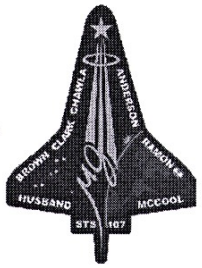

Fault Tree Closure Process

Closure Rationale Developed jointly by USA/SRBWG/DCMA

- USA Teams provided initial write-up
  - Including input from SRBWG members and DCMA
- USA SRB Chief Engineer Office Review
- SRBWG Chairman/MSFC S&MA performed individual **one-on-one** reviews with USA team lead and SRBWG discipline/hardware lead for each closure sheet
- Entire SRBWG and SRB Project Personnel performed final closeout review on each closure sheet. DCMA present at each closure discussions.

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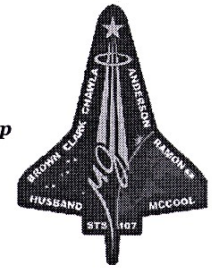
Solid Rocket Booster Working Group Agenda

SRB Working Group



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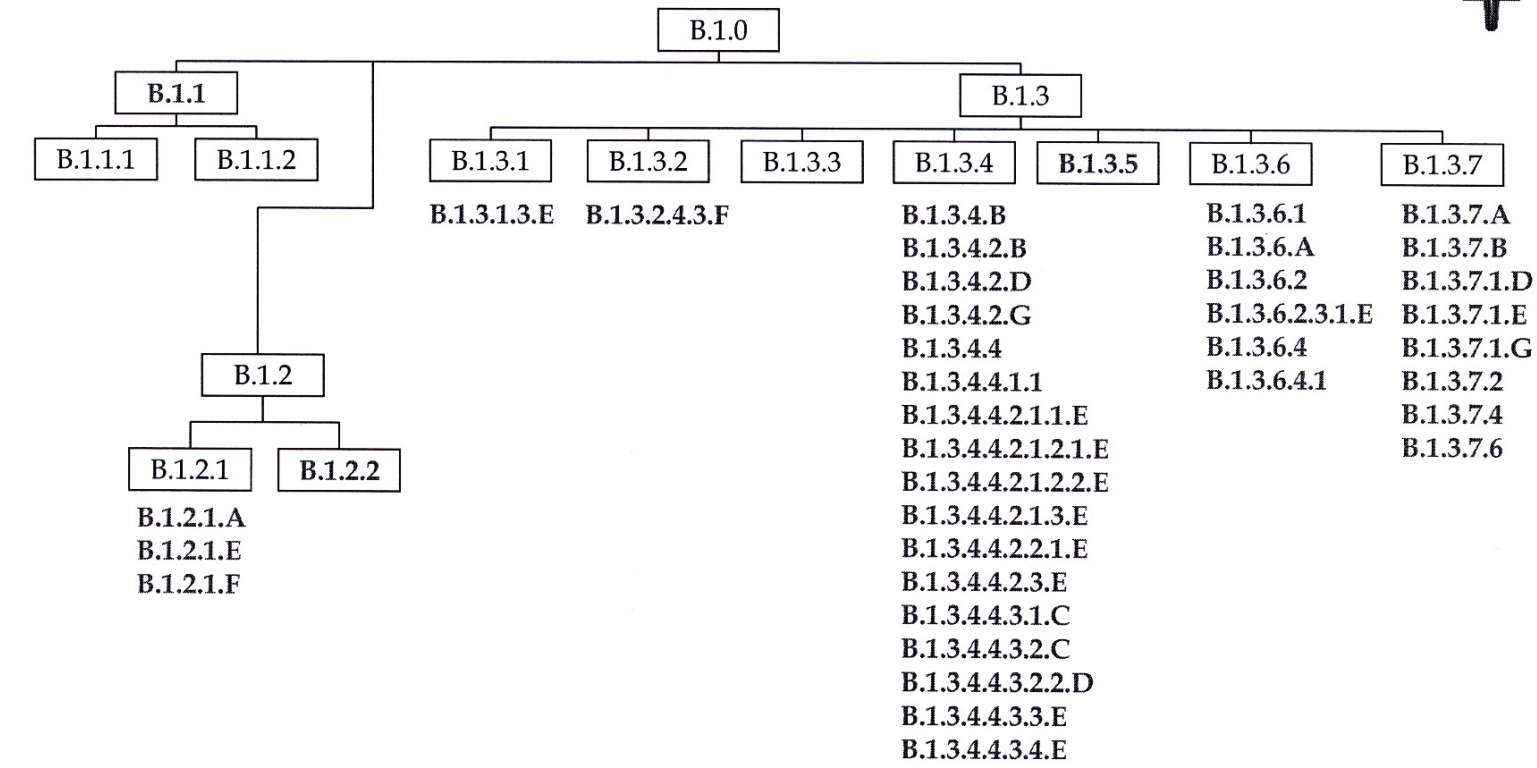
Solid Rocket Booster Working Group
Fault Tree Multi-Element Blocks

SRB Working Group



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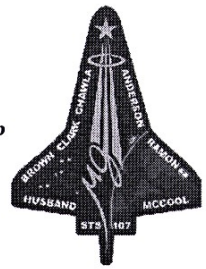
Solid Rocket Booster Working Group
SRBWG-to-MEICT Mapping

SRB Working Group



G525

B.1.3.1	B.1.3.4.4.1.A	B.1.3.6.4.1.B
B.1.3.1.1	B.1.3.4.4.1.B	B.1.3.6.4.1.1
B.1.3.2.A	B.1.3.4.4.1.1.A	B.1.3.6.4.1.2
B.1.3.2.B	B.1.3.4.4.1.1.B	B.1.3.6.5
B.1.3.2.1	B.1.3.4.4.1.1.1	B.1.3.7.A
B.1.3.2.2	B.1.3.4.4.1.1.2	B.1.3.7.B
B.1.3.2.4.A	B.1.3.4.4.2	B.1.3.7.1
B.1.3.2.4.1	B.1.3.5.A	B.1.3.7.1.1.A
B.1.3.2.4.2	B.1.3.5.B	B.1.3.7.1.1.B
B.1.3.2.4.3	B.1.3.5.C	B.1.3.7.2
B.1.3.2.4.4	B.1.3.5.1	B.1.3.7.2.B
B.1.3.2.5	B.1.3.5.2	B.1.3.7.2.M
B.1.3.3	B.1.3.6.A	B.1.3.7.2.S
B.1.3.4.A	B.1.3.6.B	B.1.3.7.3
B.1.3.4.B	B.1.3.6.1	B.1.3.7.4.1
B.1.3.4.1	B.1.3.6.1.1	B.1.3.7.4.2
B.1.3.4.1.1	B.1.3.6.2	B.1.3.7.5
B.1.3.4.2	B.1.3.6.3	B.1.3.7.6.A
B.1.3.4.2.C	B.1.3.6.3.G	B.1.3.7.6.B
B.1.3.4.2.M	B.1.3.6.4.A	B.1.3.7.6.C
B.1.3.4.2.N	B.1.3.6.4.B	
B.1.3.4.3	B.1.3.6.4.1.A	

G526

B.1.3.1
B.1.3.2.4.3
B.1.3.4.4.2
B.1.3.6.2

G649

B.1.3.6.1
B.1.3.6.1.1
B.1.3.7.1

G527

B.1.3.5.1	B.1.3.6.4.1.2
B.1.3.5.2	B.1.3.6.4.1.A
B.1.3.5.A-C	B.1.3.6.4.1.B
B.1.3.4.B	B.1.3.6.4.A
B.1.3.4.2	B.1.3.6.4.B
B.1.3.4.4.1.1.1	B.1.3.7.A
B.1.3.4.4.1.1.2	B.1.3.7.4.1
B.1.3.4.4.1.1.A	B.1.3.7.4.2
B.1.3.4.4.1.1.B	B.1.3.7.B
B.1.3.4.4.1.A	B.1.3.7.2
B.1.3.4.4.1.B	B.1.3.7.2.B
B.1.3.4.4.2	B.1.3.7.2.M
B.1.3.6.A	B.1.3.7.2.S
B.1.3.6.2	B.1.3.7.6.A-C
B.1.3.6.4.1.1	

G814

B.1.1.1.1	B.1.1.2.3.1.2.2
B.1.1.1.2.A-G	B.1.2.1, B.1.2.2
B.1.1.2.A	B.1.3.4.4.1.1.1
B.1.1.2.B	B.1.3.4.4.1.1.2
B.1.1.2.1	B.1.3.4.4.1.1.A
B.1.1.2.1.D	B.1.3.4.4.1.1.B
B.1.1.2.2	B.1.3.6.4.1.1
B.1.1.2.3	B.1.3.6.4.1.2
B.1.1.2.3.1.1.1	B.1.3.6.4.1.A
B.1.1.2.3.1.1.2	B.1.3.6.4.1.B
B.1.1.2.3.1.2.1	

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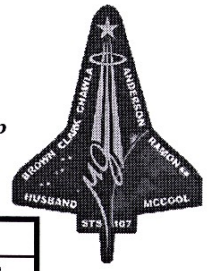
Solid Rocket Booster Working Group
Fault Tree Multi-Element (1 of 5)

SRB Working Group



FT Cause ID#	Fault Tree (FT) Block Name	Level 2
B.1.1	Anomalous Loads and Environments on SRB Adversely Affect Mission, Vehicle & Crew	G499/G814
B.1.1.1 ®	Extreme Environments Adversely Affect SRB or SRB/ET Interface	
B.1.1.1.1	Extreme Natural Environments Adversely Affect SRB or SRB/ET Interface	
B.1.1.1.2.A	Adverse Effects From Conducted or Radiated Electro Magnetic Interface (EMI)	
B.1.1.1.2.B	Adverse Aerothermal Effects During Ascent	
B.1.1.1.2.C	Adverse Vibro-Acoustic Effects While on Pad or During Ascent	
B.1.1.1.2.D	Adverse Vehicle Dynamics Effects While on Pad or During Ascent	
B.1.1.1.2.E	Adverse Aerodynamic Effects During Ascent	
B.1.1.1.2.F	Improper Venting During Ascent	
B.1.1.1.2.G	Pryo Shock While on Pad or During Ascent	
B.1.1.2 ®	Anomalous Loads Adversely Affect SRB or SRB/ET Interfaces	
B.1.1.2.1	Anomalous Loads During Prelaunch Operations	
B.1.1.2.1.D	Adverse Loads Induced by SSME Thrust Build Up	
B.1.1.2.A	Anomalous Induced Loads Caused by Holddown Stud Hangup	
B.1.1.2.2	Anomalous Loads During Ascent	
B.1.1.2.B	Anomalous Loads During Liftoff	
B.1.1.2.3	Anomalous Loads During Booster Separation	
B.1.1.2.3.1.1.1	Premature Ignition (Aft BSM)	
B.1.1.2.3.1.1.2	Low/Inadequate Thrust Output for any Two BSMs (Aft BSM)	
B.1.1.2.3.1.2.1	Premature Ignition (Forward BSM)	
B.1.1.2.3.1.2.2	Low/Inadequate Thrust Output for any Two BSMs (Forward BSM)	

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Solid Rocket Booster Working Group
Fault Tree Multi-Element (2 of 5)

SRB Working Group

FT Cause ID#	Fault Tree (FT) Block Name	Level 2
B.1.2.1	Anomalous Electrical & Instrumentation Subsystem Performance	
B.1.2.1.A	Anomalous SRB/ET Separation Performance	G499/G814
B.1.2.1.E	Anomalous SRB Guidance, Navigation & Control Performance (Rate-Gyro)	G499/G814
B.1.2.1.F	Anomalous SRB Electrical Power/Data Cable Performance	G499/G814
B.1.2.2	Anomalous Thrust Vector Control (TVC) Subsystem Performance	G499/G814
B.1.3.1	Nose Cap Assembly Damage/Malfunction Causes Debris	
B.1.3.1.3.E	Overload [Nose Cap Fastener]	G524/G526
B.1.3.2. ®	Frustum Assembly Damage/Malfunction Causes Debris	
B.1.3.2.4.3.F	Aerodynamic Loading Causes Debris	G524/G526

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Solid Rocket Booster Working Group
Fault Tree Multi-Element (3 of 5)

SRB Working Group

FT Cause ID#	Fault Tree (FT) Block Name	Level 2
B.1.3.4 ®	Forward Skirt Assembly Damage/Malfunction Causes Debris	
B.1.3.4.B	Loss of Elec. Breakaway Cables & Connector Components (Sep. Plane) Causes Debris [Fwd Skirt]	G524/G526
B.1.3.4.2.B	Loss of Thrust Post Attach Components Causes Debris	G524/G527
B.1.3.4.2.D	Loss of Forward Skirt/RSRM Interface Hardware Causes Debris	G524/G527
B.1.3.4.2.G	Loss of SRB Fwd Crossover Components Causes Debris	G524/G527
B.1.3.4.4	Loss of Fwd. ET Attach Components Causes Debris	G524/G527
B.1.3.4.4.1.A	Debris Due to No Separation	
B.1.3.4.4.1.B	Debris Due to Premature Separation	
B.1.3.4.4.1.1	Debris Due to Improper Separation	G499/G814
B.1.3.4.4.1.1.A	Failure Outside of Fracture Plane Causes Debris	
B.1.3.4.4.1.1.B	Recontact Causes Debris	
B.1.3.4.4.1.1.1	Material Defects Causes Debris	
B.1.3.4.4.1.1.2	Manufacturing Defect Causes Debris	
B.1.3.4.4.2.1.1.E	Overload [RSS Crossover Fastener]	G524/G526
B.1.3.4.4.2.1.2.1.E	Overload [RSS Crossover Disconnect Housing]	G524/G526
B.1.3.4.4.2.1.2.2.E	Overload [RSS Crossover Subparts]	G524/G526
B.1.3.4.4.2.1.3.E	Overload [RSS Crossover Gimbal Cover]	G524/G526
B.1.3.4.4.2.2.1.E	Overload [RSS Crossover Fastener (ET side)]	G524/G526
B.1.3.4.4.2.3.E	Overload [RSS Crossover Gimbal Cover Fastener]	G524/G526
B.1.3.4.4.3.1.C	Overload [Bolt Catcher Attach Fastener]	G524/G526
B.1.3.4.4.3.2.C	Excessive Aerodynamic Loading	G524/G526
B.1.3.4.4.3.2.2.D	Excessive Force From Separation Bolts	G524/G526
B.1.3.4.4.3.3.E	Overload [Bolt Catcher ET Thrust Fitting or Inserts]	G524/G526
B.1.3.4.4.3.4.E	Excessive Separation Bolt Loading Causes Debris	G524/G526

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Solid Rocket Booster Working Group
Fault Tree Multi-Element (4 of 5)

SRB Working Group

FT Cause ID#	Fault Tree (FT) Block Name	Level 2
B.1.3.5 ®	Tunnel Cover/Floor Plate Assembly Damage/Malfunction Causes Debris	G524/G527
B.1.3.5.1	Loss od Thermal Protection System (TPS) Causes Debris [Tunnel Cover/Floor Plate Assembly]	
B.1.3.5.A	Structural Damage to Tunnel Cover Assembly Caiuses Debris	
B.1.3.5.B	Loss of Electrical Cables and Connector Components causes Debris [Tunnel Cover/Floor {Plate Assy]	
B.1.3.5.2	Loss of Tunnel over/Floor Plate Components Causes Debris (SRB/RSRM)	
B.1.3.5.C	Improper Operation of Pyrotechnic Components Causes Debris [Tunnel Cover//Floor Plate Assembly]	
B.1.3.6 ®	ETA Ring/Aft Attach Strut Assembly Damage/Malfunction Causes Debris	
B.1.3.6.A	Loss of Elec. Breakaway Cables & Connector Components (Sep. Plane) [ETAR/Aft Attach Strut Assy]	G524/G527
B.1.3.6.1	Loss of Thermal Protection System (TPS) Causes Debris [ETAR/Aft Attach Strut Assy]	G524/G649
B.1.3.6.2	Aft Strut Component Failure (ET Strut Half)	G524/G527
B.1.3.6.2.3.1.E	Overload [Aft Strut ET Fastener]	G524/G526
B.1.3.6.4	Aft Separation Bolt Components Causes Debris	G524/G527
B.1.3.6.4.A	No Separation Causes Debris	
B.1.3.6.4.B	ETA Ring Structural Failure	
B.1.3.6.4.1	Improper Separation Causes Debris	G499/G814
B.1.3.6.4.1.A	Failure Outside of Fracture Plane Causes Debris	
B.1.3.6.4.1.B	Recontact Causes Debris (Strut Half)	
B.1.3.6.4.1.1	Material Defects Causes Debris	
B.1.3.6.4.1.2	Manufacturing Defect Causes Debris	

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Solid Rocket Booster Working Group
Fault Tree Multi-Element (5 of 5)

SRB Working Group

FT Cause ID#	Fault Tree (FT) Block Name	Level 2
B.1.3.7 ®	Aft Skirt Assembly Damage/Malfunction Causes Debris	
B.1.3.7.A	Loss of Electrical Breakaway Cables & Connector Components (Separation Plane) [Aft Skirt]	G524/G527
B.1.3.7.B	Aft Skirt Assembly Structural Failure Causes Debris	G524/G527
B.1.3.7.1.D	Loss of RT455 without Hypalon From Aft Skirt Assembly Causes Debris	G524/G649
B.1.3.7.1.E	Loss of BTA without Hypalon From Aft Skirt Assembly Causes Debris	G524/G649
B.1.3.7.1.G	Loss of RTV133/RTV108 From Aft Skirt Assembly Causes Debris	G524/G649
B.1.3.7.2	Loss of Aft Skirt Components Causes Debris	G524/G527
B.1.3.7.4	Improper Operation of Pyrotechnic Components Causes Debris [Aft Skirt]	G524/G527
B.1.3.7.4.1	Improper Operation of SRB/MLP Holddown Release	
B.1.3.7.4.2	Improper Operation of Booster Separation Motor Ignition Components	
B.1.3.7.6	Loss of MLP Holddown Components Causes Debris	G524/G527
B.1.3.7.6.A	Loss of Aft Skirt Shoe Hardware Causes Debris (includes Shims and Ground Straps)	
B.1.3.7.6.B	Loss of GN2 Purge Line Assembly Causes Debris	
B.1.3.7.6.C	Loss of Holddown Hardware Causes Debris (includes Stud Washer, Nut & Breaklink Nut)	

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Fault Tree Block Presentation Sequence

SRB Working Group

File #	Block ID.	Order of Presentation	Number of Closure Sheets	Title or related areas
File #1	B.1.1	6	18	Anomalous Loads and Environments on SRB Adversely Affect Mission, Vehicle and Crew
File #2	B.1.2	7	2	Anomalous Performance of Active Subsystems
File #3	B.1.3.1	5	2	Nose Cap Assembly Damage/Malfunction Causes Debris
File #4	B.1.3.2 B.1.3.3	2	11	Frustum Assembly Damage/Malfunction Causes Debris, Parachutes
File #5	B.1.3.4	1	20	Forward Skirt Assembly Damage/Malfunction Causes Debris
File #6	B.1.3.5 B.1.3.6	4	19	Tunnel Cover/Floor Plate, ET Attach Ring and Aft Attach Strut Cause Debris
File #7	B.1.3.7	3	16	Aft Skirt Assembly Damage/Malfunction Cause Debris
File #8				Executive Summary/Presentation
		Total	**88**	

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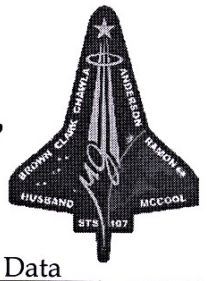
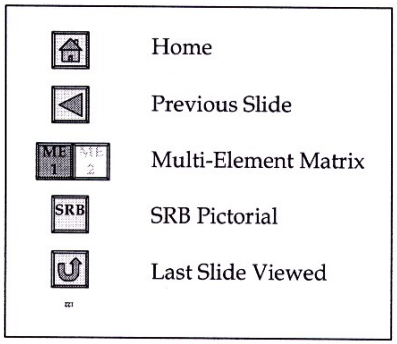
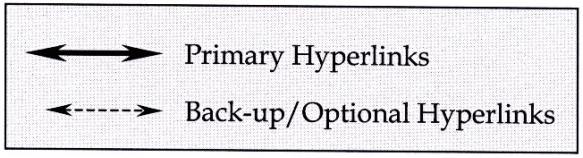
Fault Tree Block Presentation Sequence

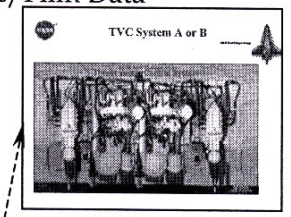
SRB Working Group



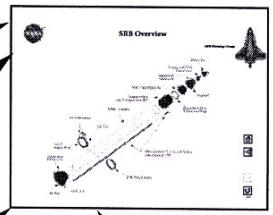




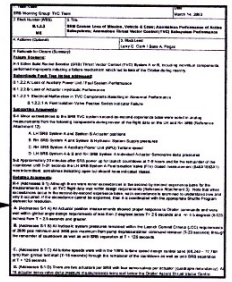
Photographic/Film Data



SRB Pictorial



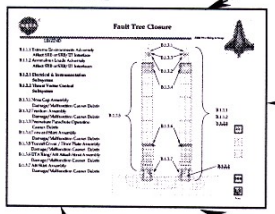
Fault Tree Block Closure Sheet

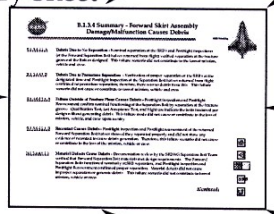


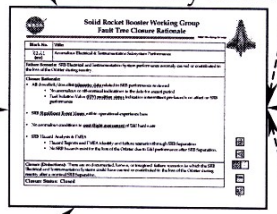
Fault Tree Branch Summary Sheet

Fault Tree Block Summary Sheet

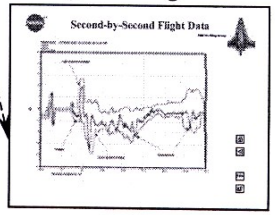
Home



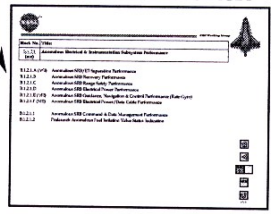


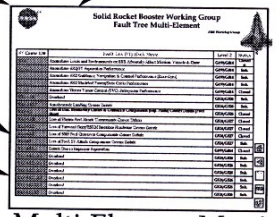


Engineering Data



Fault Tree Branch





Multi-Element Matrix

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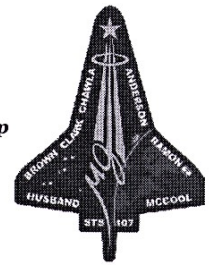
Solid Rocket Booster Working Group Agenda

SRB Working Group



- List of Members, Advisors, Observers, and Others
- Method of Investigation
  - Working Group Organization
  - Special Circumstances
  - Investigation Process
- Fault Tree Closure Summary
- Summary

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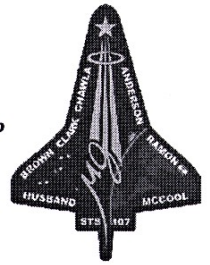
Summary



- All Multi-Element Fault Tree Blocks Have Been Addressed Individually or as a Sub-Block to a Higher Level Closure Sheet.
- All SRB Systems Performed Nominally within Specifications and with No Unexplainable Experience-Base Deviations.
- Solid Rocket Boosters are Known STS Debris Generators:
  - All Debris Generating Events Have Been Identified
    - Debris at Liftoff
    - Debris during Flight
    - Debris at Separation
    - Debris after Separation
- Four Bolt Catcher Fault Tree Blocks Remain Open until after Testing is Complete (Estimated Completion 6/9/03).
- Investigation Results Thus Far Indicate SRBs did not Cause Loss of STS-107.

SRB Launch through Recovery Environments

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