



**NOAA N-PRIME Mishap Investigation**  
**Final Report**

**September 13, 2004**

**NASA**

NATIONAL AERONAUTICS  
AND SPACE ADMINISTRATION



October 4, 2004

Reply to Attn of:

General Law Practice Group

TO: Deputy Associate Administrator, Science Mission Directorate

FROM: Associate General Counsel for General Law (Acting)

SUBJECT: Review of NOAA N Prime Mishap Report

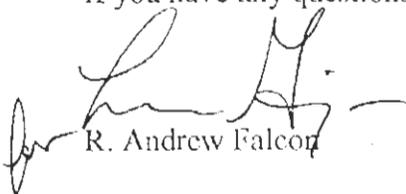
As requested on September 27, 2004, we have completed our review of the NOAA N Prime Mishap Report (Report) under NASA Procedural Requirements (NPR) 8621.1, "Procedural Requirements for Mishap Reporting, Investigating, and Recordkeeping." We also reviewed the endorsement pages from the Deputy Associate Administrator of the Science Mission Directorate and the Chief, Office of Safety and Mission Assurance. Based on our review, we recommend releasing the Report subject to the comments below.

In an e-mail from Jeff Smith, Director, Civil Space West Coast Operations, Lockheed Martin, dated October 1, 2004, Lockheed Martin has identified several sections of the report which include information that they consider proprietary information. Also, the External Relations Office has identified information in the Report which is export controlled. Both the proprietary information and the export-controlled information should be redacted before release of the Report.

Moreover, for your information, under NPR 8621.1, "the objective of mishap and close call investigations is to improve safety by identifying what happened, where it happened, when it happened, why it happened, and what should be done to prevent recurrence and reduce the number and severity of mishaps." This mishap investigation focuses on the cause of the mishap and does not determine legal or contractual liability. In contrast, there was also a legal investigation of this mishap which was used to determine legal and contract liability.

We note that the Report has several appendices. We recommend that our office review any appendices prior to release.

If you have any questions about this review please contact Dan Thomas on (202) 358-2085.

  
R. Andrew Falcon

# Mishap Investigation Report Endorsement



Report Title: NOAA N-Prime Mishap Investigation Report

Date of Report: September 13, 2004

Recommend Approval	Recommend Rejection	Endorsement and Comments
<p><b>X</b></p>		<p>The NOAA N-Prime Mishap Investigation Report has been prepared as directed by the appointment letter.</p> <p>The executive summary consolidates findings in such a way that the information is misleading. A better summary of the findings is found in Table 7-1 and Table 7-2.</p> <p>I accept the findings as described in the NOAA N-Prime Mishap Investigation Report, but do not agree that all the findings presented are causes of the mishap but rather observations documenting systemic problems.</p> <ul style="list-style-type: none"> <li>• I agree with the MIB that the proximate cause is the failure to install the 24 bolts that would hold the turn-over-cart adapter plate to the turn-over cart.</li> <li>• I agree that the following findings presented in the report were root causes: L-3a, L-5, L-8, G-1, G-4, G-6, G-7, and G-9. (Finding L-4 is a weak root cause because it is not substantiated with sufficient facts.) However, I disagree that the remaining findings are root causes. I believe finding L-2 is a missed opportunity, and the other findings are observations because they did not cause or contribute to the proximate causes stated in the report (and above): L-2, L-4, L-6, L-7, L-9, L-10, L-11, L-12, L-13, G-2, G-3, G-5 and G-8.</li> </ul> <p>Appendix E has an event and causal factor tree which is different from the graphical representation presented in Chapter 5. Appendix E is clearer, more complete and has logical flow and should be used over the graphical representations in Chapter 5.</p> <p>The report provides recommendations for each of the findings, however, in some cases the recommendations do not fully address the topic described in the findings.</p> <ul style="list-style-type: none"> <li>• I concur with the following recommendations as written: LM2, LM3, LM5, LM6, G1, G4, G6, G7, G8.</li> <li>• I have added recommendations to supplement the MIB recommendations which I considered unverifiable or limited because this would not prevent the occurrence of a similar mishap.</li> <li>• Additional comments and recommendations can be found in an attached critique sheet.</li> </ul>

**NASA Endorsing Official**

<p>Signature <i>Bryan O'Connor</i></p>	<p>Date of Endorsement 28 SEP 04</p>
<p>Printed Name Bryan O'Connor</p>	<p>Title Chief Office of Safety and Mission Assurance</p>



## OSMA's Critique of NOAA N-Prime Mishap Investigation Board Report

OSMA's Categorization of Findings	MIB Report Finding No.	MIB Finding Text (From pg. 58-59 of MIB Report)	OSMA's Opinion Do Facts Substantiate Finding/Comments?	MIB's Recommendations For Each Finding  (From pg. 89 or 93 of the MIB report)  <small>*In some cases, the MIB report listed multiple recommendations for a finding. These are shown below.</small>	OSMA's Opinion Concerning Whether Recommendation Addresses Finding	OSMA's Recommendations
	<b>L-3 Cont.</b>			R5 B) Establish an effective safety program with a well-defined system safety policy and mandatory requirements. Safety awareness must be promoted to all levels of the organization through a training program or a training module within other applicable training programs.	R5) Yes, the recommendation addresses the finding. Safety awareness at all levels may assist the RTE in calling safety when it is required.  However, management attention to behavior modification would also help.  There was a requirement for safety, but not for an operational safety observer.	
Root Cause (weak)	L-4	Adverse mental states in the forms of "channelized attention", "complacency", and "get-home-itis" resulted in an accelerated pace of operations and procedure execution.	Limited: Although this could have played a role in the mishap, the report gives only limited evidence for conclusions in the finding. Though the team characterizes their operation as "routine" and admitted to being focused on their task, this is not evidence of complacency. Furthermore, there is no discussion of "get home-it is" in the report.	R1) Provide a formal training program for certifying all test conductor and for training all I&T personnel of their roles and responsibilities.  Provide periodic refresher training to reinforce these roles and responsibilities	R1) The recommendation is limited.  Training on roles and responsibilities does not address the finding.	OSMA 6)  Make missing bolts more easily detectable (e.g., with color) and require technicians wiping surfaces to perform a visual inspection and stamp the procedure indicating that they did the verification step.
				R8) Establish a training program to disseminate lessons learned from this and other mishaps.	R8) The recommendation is limited.  Training on roles and responsibilities does not address the finding.	

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<p>Root Cause –</p> <p>The poor communication and coordination <u>between the projects</u> was a root cause for why RTE did not know the TOC was configured incorrectly.</p> <p>The cause statement includes both root cause and observation.</p>	L-5	<p>“Substandard crew resources” included poor hand-off between the DMSP and TIROS Projects regarding the TOC, late identification of personnel to work Saturday, and poor red-tagging process for GSE.</p>	<p>Facts substantiate finding that there was poor “hand-off” / communication/ coordination between the DMSP and TIROS projects.</p> <p>Facts substantiate poor red-tagging process for GSE, however red-tagging was not required for the TOC configuration change. Consequently, all information concerning red-tags are not causes, rather they are observations.</p>	R3) Establish effective process guidelines for regulating the I&T environment, including operations planning, procedure development, red lining, procedure execution discipline, and configuration management.	<p>R3) Yes, the recommendation addresses the finding. Configuration management of GSE and logs of changes made to GSE would eliminate the root cause.</p> <p>The rest of these recommendations address the observation, and the not the causes of the mishap.</p>	
<p>Observation – late planning</p> <p>Observation – poor crew make-up for team</p>	L-6	<p>“Planned an inappropriate operation”- The team was formed late in a hurried fashion with an atypical mix of personnel.</p>	<p>Facts substantiate finding that the team was formed late, however, this formation occurred prior to the day of the operation and did not cause the RTE's decision error, or the PQC and PA violations.</p>	<p>R3) Establish effective process guidelines for regulating the I&amp;T environment, including operations planning, procedure development, red lining, procedure execution discipline, and configuration management.</p> <p>R2) Provide supervisory training to promote an active supervisory role in identifying, monitoring, and correcting poor process discipline and other deficiencies.</p>	<p>R3) Yes, the recommendation addresses the finding.</p> <p>R2) Yes, the recommendation addresses the finding. This should focus on forming a “good team” if that is the problem it is trying to fix.</p>	

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Observation	L-7	"Inadequate supervision" was manifested in the lack of clear definition and enforcement of roles and responsibilities among the team individuals, consequently individuals failed to fulfill their expected roles and responsibilities.	<p>This finding is based on a "pre-task briefing" for the lifting operation which was only given to part of the team.</p> <p>This pre-task occurred after the TOC was verified for use, and so it did not influence the RTE decision error or the PQC and PA violations.</p> <p>Nowhere in this report does it describe who was confused about their roles and responsibilities.</p> <p>Page 77 of the MIB report has a discussion of roles and responsibilities but there are no facts to substantiate the personnel did not know what they were supposed to be doing. In fact, page 36 of the report shows the experience level of the team members, and indicates that all members had considerable experience.</p>	<p>R2) Provide supervisory training to promote an active supervisory role in identifying, monitoring, and correcting poor process discipline and other deficiencies.</p> <p>R7) Closed Circuit Video Monitoring as an aid to supervision and promote performance monitoring,</p>	<p>R2) The recommendation is limited. This recommendation does not address the finding dealing with "inadequate supervision" that was based on discussions of a pre-task briefing (pg 53-54).</p> <p>R7) Unsubstantiated. This does not address the finding.</p> <p>This recommendation would not correct the inadequate pre-task briefing described in 5.5.3 or make personnel understand their roles and responsibilities, but it could be useful as part of recommendation OSMA 5) in the context of improving management accountability for performance.</p>	OSMA 7) Training should include how to perform a good pre-task briefing.
Root Cause – Supervisors failed to recognize and correct known problems	L-8	"Failure to correct known problems" was a supervisory failure to correct similar known problems. PA supervisors routinely allowed PA inspector sign-off after the fact. I & T supervisors routinely allowed poor test documentation.	<p>Facts to support this are confusing.</p> <p>The MIB makes statements about supervisors of the PA and I&amp;T but does not indicate if these supervisors were interviewed.</p> <p>The DCMA reports may substantiate this finding. (Pg 78)</p>	R2) Provide supervisory training to promote an active supervisory role in identifying, monitoring, and correcting poor process discipline and other deficiencies.	R2) Yes, but the recommendation is limited.	

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				R6) Establish an effective monitoring, trending, verification, and audit program to manage the performance and deficiencies of the I&T activities	R6) Yes, the recommendation addresses the finding.	
Observation	L-9	"Supervisory Violation" was committed by repeatedly waiving required presence of quality assurance and safety and bypassing Government Mandatory Inspection Points.	Facts documented in the report to not substantiate this finding.  MIB report section 5.3.3.1 says safety was not notified because safety was not considered an essential element of the operation. Note that this safety person was a system safety engineer that was to make comments about safety precautions in the procedure and not necessarily provide operational safety support. Also, page 42 (paragraph 5.3.3.3) states that the DCMA representative was unaware that there was a Mandatory Inspection Point. This means that he did not waive the inspection point. He just did not know about it.	R2) Provide supervisory training to promote an active supervisory role in identifying, monitoring, and correcting poor process discipline and other deficiencies.	R2) The recommendation is limited. This does not address the finding per se. It should be supplemented per recommendation OSMA 5).  Violations are not corrected through training. Violations are corrected through behavior modification that includes reinforcing the desired performance.	

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Observation	<b>L-10</b>	In "resource management", MIB observed inadequate emphasis on safety, and inadequate quality assurance support to provide effective coverage.	Fact: Safety was not contacted. This shows an inadequate emphasis on safety.  However, this does not show that the safety program or the quality program was inadequate.	R4) Review and staff PA and safety personnel support according to requirements.	R4) The recommendation is limited.  Page 78 states that there are only a few safety requirements.  These do not address the need for an operational safety person (vs. system safety engineer).	OSMA 8) Generate additional safety requirements to ensure that an operational safety person is present during operations.  List the safety person's roles and responsibilities.  Enforce the policy that requires the safety person's presence during operations (hazardous and critical).
Observation	<b>L-11</b>	The "Organization climate" in the I&T domain with an operational program has engendered an unhealthy environment that led to complacent and overconfident attitudes toward routine operations.	Limited discussion to substantiate "complacency" or "overconfidence."	R3) Establish effective process guidelines for regulating the I&T environment, including operations planning, procedure development, red lining, procedure execution discipline, and configuration management.	R3) Yes, the recommendation addresses the finding.	

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				R5) Establish an effective safety program with a well-defined system safety policy and mandatory requirements. Safety awareness must be promoted to all levels of the organization through a training program or a training module within other applicable training programs.	R5) This should not be construed to be limited to the safety organization. It applies to the whole organization.	
Observations	L-12	Lack of effective "Organizational Processes" in the form of guideline and safeguards to regulate the I&T environment.	Weak link to facts.  This is based on redlines in documents and poor planning.  These were not causal factors.	R3) Establish effective process guidelines for regulating the I&T environment, including operations planning, procedure development, red lining, procedure execution discipline, and configuration management.	R3) Yes, the recommendation addresses the finding.	
				R6) Establish an effective monitoring, trending, verification, and audit program to manage the performance and deficiencies of the I&T activities.	R6) Yes, the recommendation addresses the finding.	
				R7) Closed Circuit Video Monitoring as an aid to supervision and promote performance monitoring.	R7) The recommendation is limited. This recommendation does not address the finding.	
				R8) Establish a training program to disseminate lessons learned from this and other mishaps.	R8) The recommendation is limited.  Training on roles and responsibilities does not address the finding.	

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Observation	L-13	Ineffective System Safety Program.	No facts to substantiate this.	R5) Establish an effective safety program with a well-defined system safety policy and mandatory requirements. Safety awareness must be promoted to all levels of the organization through a training program or a training module within other applicable training programs.	R5) This should not be construed to be limited to the safety organization. It applies to the whole organization.	
Root Cause	G-1	The government quality assurance and safety provided "inadequate oversight". Oversight function became "issue driven". Procedures rarely reviewed; non-conformances not trended; rarely make impromptu inspections.	Fact does not substantiate the entire finding. Some facts included in the MIB report conflict with finding.  MIB report paragraph 5.2.4 states that DCMA or QA is not required on procedures at any level.  Facts do support that there was little audit and inspection.	G-R4) Establish effective oversight guideline for I&T operations planning, procedure development, and procedure execution discipline.	G-R4) Yes, the recommendation addresses the finding.	
Observation	G-2	In substituting for the DCMA, the QAR failed to enforce a Government Inspection Point by failing to enforce his presence at the operation.	Facts conflict: Report states that QAR did not know that there was a Mandatory Inspection Point (pg 42).	G-R2) Establish and document clear roles and responsibilities for the contractor in-plant representatives.  Revise Letter of Delegation for DCMA and Letter of Assignment for QAR	G-R2) Yes, the recommendation addresses the finding. However, this is limited unless training conveys the roles and responsibilities.	

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Observation	G-3	Government has very limited safety oversight.	Paragraph referenced in the report does not describe govt. oversight.  Facts are not clear.	G-R5) Establish an effective safety oversight program. Ensure Safety Program Plan is updated and hazard analysis is performed. Increase safety oversight and provide safety training.	G-R5) Yes, but this does not address the finding completely.  The report does not say that the safety program plan was bad nor does it say that a hazard analysis had not been completed.	
Root Cause – Government failed to correct known problems.	G-4	Government "failed to correct known problems" such as PA signoff after the fact and poor test documentation.	Facts in report substantiate this finding.	G-R4) Establish effective oversight guideline for I&T operations planning, procedure development, and procedure execution discipline.	G-R4) Yes, but the corrective action plan should include detail about who does the oversight.	
				G-R6) Coordinate with the contractor to implement an effective oversight program to monitor, trend, verify and audit the contractor performance and deficiencies.	G-R6) Yes, this recommendation addresses the finding.	
Observation – Resource management increased tempo of the operations.	G-5	Deficient "resource management" include: rapid trade-offs between the schedules, staffing and milestones for the two remaining satellites exacerbated the already fast operational tempo of the LMSSC I&T team, lack of resources in the safety area.	Facts substantiate finding that there was a schedule trade off and this affected the tempo of the planning.  There are not facts to substantiate that safety lacked resources.	G-R3) Provide sufficient resource for DCMA to fulfill the Letter of Delegation and for the on-site government support to fulfill the Letter of Assignment.	G-R3) Yes, but the recommendation should focus on resource management, not just resource level.	
				G-R5) Establish an effective safety oversight program. Ensure Safety Program Plan is updated and hazard analysis is performed. Increase safety oversight and provide safety training.	G-R5) Yes, this is a good recommendation but this does not address the finding.  The report does not say that the safety program plan was bad nor does it say that a hazard analysis had not been completed.	

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Root Cause – DCMA had a number of written corrective actions, which they did not follow up on. Could be considered "lax oversight."	G-6	Unhealthy "organizational climate" factors include: using retired LMSSC employees as government representatives, lax and casual oversight toward an I&T environment with routine operations.	No facts substantiate that the use of retired employees was problematic. There was only speculation that because the employee was retired, he may not have exercised objective oversight. (Pg 42)  Facts: DCMA had written corrective action reports but failed to follow-up. (pg 43)	G-R1) Provide a dedicated, full time government in-plant representative as indication of commitment and support.	G-R1) Yes, as long as the person has fulltime meaningful work to do.	
				G-R2) Establish and document clear roles and responsibilities for the contractor in-plant representatives.  Revise Letter of Delegation for DCMA and Letter of Assignment for QAR.	G-R2) No. This recommendation does not address the finding unless it completely rules out the use of retired LMSSC employees.	
				G-R4) Establish effective oversight guideline for I&T operations planning, procedure development, and procedure execution discipline.	G-R4) The recommendation is limited. See suggested recommendation OSMA 1) for supplemental recommendation.	OSMA 9) Establish close-loop system to track all corrective actions to closure and develop a plan to periodically audit to verify that the problem has not reoccurred.
Root Cause	G-7	Government lacks "organizational processes" to effectively monitor, verify, and audit the performance and effectiveness of the I&T processes and activities.	Facts substantiate the finding.	G-R4) Establish effective oversight guideline for I&T operations planning, procedure development, and procedure execution discipline.	G-R4) Yes, the recommendation addresses the finding.	
				G-R6) Coordinate with the contractor to implement an effective oversight program to monitor, trend, verify and audit the contractor performance and deficiencies.	G-R6) Yes, the recommendation addresses the finding.	
				G-R8) Periodic independent reviews should be conducted to review Project status and performance	G-R8) Yes, the recommendation addresses the finding.	

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Observation	<b>G-8</b>	The government safety program placed an overemphasis on launch site safety and inadequate in-plant safety.	This was mentioned but not explained.	G-R5) Establish an effective safety oversight program. Ensure Safety Program Plan is updated and hazard analysis is performed. Increase safety oversight and provide safety training.	G-R5) Yes, but this does not address the finding.  The report does not say that the safety program plan was bad nor does it say that a hazard analysis had not been completed.	
Root Cause	<b>G-9</b>	Deficient DCMA CAR assessment and reporting processes.	Facts substantiate this finding.	G-R7) DCMA to evaluate the effectiveness of their assessment processes and formulate corrective measures.	G-R7) Yes, the recommendation addresses the finding.	

# Mishap Investigation Report Endorsement



Report Title: NOAA N-Prime Mishap Investigation Report  
 Date of Report: September 13, 2004

Recommend Approval	Recommend Rejection	Endorsement and Comments
<p><b>X</b></p>		<p>The NOAA N-Prime Mishap Investigation Report has been prepared as directed by the appointment letter, and the requirements specified in NPR 8621.1A.</p> <p>Since the report was written, the assessment of the hardware damage has been completed.</p> <p>The report meets the intent of the authorizing letter and covers all the required material. Proper analysis techniques were selected and executed.</p> <p>The report describes the proximate cause, root causes, and contributing factors.</p> <p>The mishap report shows that sufficient facts were determined to adequately substantiate the findings.</p> <p>The report provides recommendations that track with the findings.</p> <p>The eight recommendations for Lockheed Martin are practical, feasible, and achievable. Implementation by Lockheed Martin should prevent the recurrence of a similar mishap.</p> <p>The eight recommendations for GSFC and DCMA are practical, feasible, and achievable. Implementation by GSFC and DCMA should provide adequate government supervision to prevent the recurrence of a similar mishap.</p> <p>I concur with the eight Lockheed Martin and eight government recommendations.</p>

## NASA Endorsing Official

Signature

Date of Endorsement

Sept. 28, 2004

Printed Name

Ghassem Asrar

Title

Deputy Associate Administrator  
 Science Mission Directorate

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SECTION I

NOAA N-PRIME MISHAP INVESTIGATION BOARD

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NOAA N-PRIME MISHAP INVESTIGATION BOARD ADVISORS

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Thomas Berndt  
Legal Advisor  
Deputy Chief Counsel  
NASA Ames Research Center

 13 Sept. 2004

NOAA N-PRIME MISHAP INVESTIGATION BOARD SIGNATURES

EXECUTIVE SECRETARY

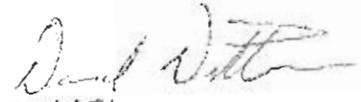
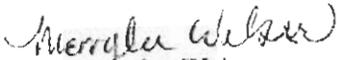
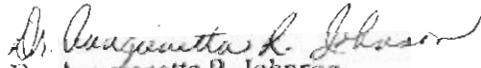
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National Aeronautics and  
Space Administration

**Headquarters**

Washington, DC 20546-0001

September 17, 2004



Reply to Attn of:

TO: Distribution

FROM: Deputy Associate Administrator for Science

SUBJECT: Revision to Mishap Investigation Board for NOAA-N'

The membership of the Mishap Investigation Board for NOAA-N', consisting of the chairperson, members of the board, ex officio representative, and supporting staff is modified as follows:

**Chairperson:**

1. Mr. Christopher Scolese  
NASA Headquarters - Science Mission Directorate  
Washington, DC

**Voting Members:**

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Ames Research Center (For Code Q)  
Sunnyvale, CA
2. Mr. Malcolm Glenn  
Kennedy Space Center  
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3. Mr. Richard A. Foss  
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Greenbelt, MD

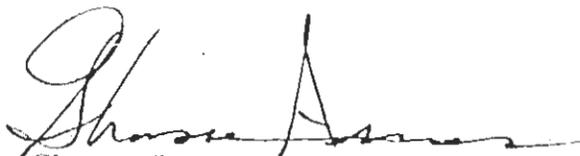
**Advisors:**

1. Mr. Carl Weber  
NASA Headquarters – Office of Procurement  
Washington, DC
2. Lynne W. Baillets – Office of Procurement  
NASA Headquarters  
Washington, DC
3. Dr. Annjenetta R. Johnson - Office of the Chief Engineer  
NASA Headquarters/Code D  
Washington, DC
4. Ms. Merrylee Weber - Office of Safety and Mission Assurance  
NASA Headquarters/Code Q  
Washington, DC
5. Tom Berndt  
NASA Ames Research Center  
Moffett Field, CA
6. Robert Navarro  
NASA Ames Research Center  
Moffett Field, CA
7. Daniel Dittman  
NASA Ames Research Center  
Moffett Field, CA
8. Gary Davis  
National Oceanic and Atmospheric  
Administration  
Silver Spring, MD

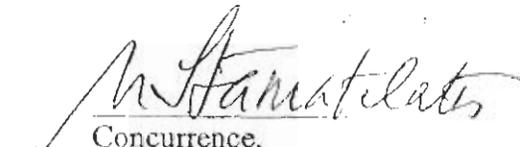
9. Wilfred Mazur  
National Oceanic and Atmospheric Administration  
Silver Spring, MD

Consultant:

1. James Lumsden  
NASA Jet Propulsion Laboratory  
Pasadena, CA
2. Dr. Scott Schappell  
Federal Aviation Administration  
Civil Aeromedical Institute



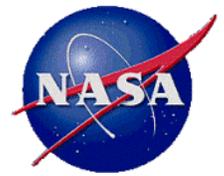
Ghassem R. Asrar



Concurrence,  
Bryan D. O'Connor

Distribution:

Office of Safety and Mission Assurance/Mr. O'Connor  
Office of Safety and Mission Assurance/Ms. Weber  
Science Mission Directorate/Dr. Weiler  
Science Mission Directorate/Mr. Scolese  
Office of the Chief Engineer/Dr. Johnson  
Office of the General Counsel/Mr. Pastorek  
Office of the General Counsel/Ms. Reilly  
Office of Procurement/Mr. Luedtke  
Mission and Systems Management/Mr. Luther  
Mission and Systems Management /Mr. Nichols  
GSFC/100/Mr. Diaz  
GSFC/300/Ms. Harper  
KSC/AA/Mr. Kennedy  
KSC/SA-B1/Mr. Glenn  
LaRC/106/Mr. Bridges  
LaRC/424/Mr. Foss  
ARC/200-1/Mr. Hubbard  
ARC/213-10/Dr. Panontin  
NOAA/Mr. Withee  
NOAA/Mr. Davis  
DOD/Gen. Dickman  
DOD/Col. Horejsi



# **NOAA N-PRIME Mishap Investigation**

## **Final Report**

**September 13, 2004**

**NASA**

**NATIONAL AERONAUTICS**  
**AND SPACE ADMINISTRATION**

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WITNESS INTERVIEWS/STATEMENTS\*

MISHAP INVESTIGATION BOARD ACTIVITIES SUMMARY\*

**\* UNDER SEPARATE COVER.**

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**SECTION 1**

**NOAA N-PRIME MISHAP INVESTIGATION BOARD**

Christopher Scolese  
Deputy Associate Administrator  
for Space Science, NASA Headquarters  
Chairman

Richard A. Foss  
Chief, Systems Integration and Test Branch  
Langley Research Center, NASA

Malcolm Glenn  
Mission Assurance Engineer  
Shuttle Processing  
Kennedy Space Center, NASA

Colonel James R. Horejsi  
Chief Engineer  
Space and Missile Systems Center  
Air Force Space Command

Dr. Tina L. Panontin  
Chief Engineer  
Ames Research Center, NASA

Abigail Harper  
Deputy Director, Office of Safety and  
Mission Assurance  
Goddard Space Flight Center, NASA  
Ex-Officio Member

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**NOAA N-PRIME MISHAP INVESTIGATION BOARD ADVISORS**

Thomas Berndt  
Legal Advisor  
Deputy Chief Counsel  
NASA Ames Research Center

**SECTION 2**

**NOAA N-PRIME MISHAP INVESTIGATION BOARD STAFF**

Richard Ho	Executive Secretary	NASA Goddard Space Flight Center
James Lumsden	Consultant	NASA Jet Propulsion Laboratory
Carl Weber	Advisor	NASA Headquarters/Code H
Lynn W. Bailets	Advisor	NASA Headquarters/Code H
Merrylee Weber	Advisor	NASA Headquarters/Code Q
Dr. Anngienetta R. Johnson	Advisor	NASA Headquarters/Code Y
Robert Navarro	Advisor	NASA Ames Research Center
Daniel Dittman	Advisor	NASA Ames Research Center
Gary Davis	Advisor	National Oceanic and Atmospheric Administration
Wilfred Mazur	Advisor	National Oceanic and Atmospheric Administration
Dr. Scott Schappell	Consultant	Federal Aviation Administration Civil Aeromedical Institute

## SECTION 3

### EXECUTIVE SUMMARY

On Saturday, September 6, 2003 during an operation at Lockheed Martin Space Systems Company (LMSSC) Sunnyvale that required repositioning the Television Infrared Observational Satellites (TIROS) National Oceanic and Atmospheric Administration (NOAA) N-Prime satellite from a vertical to a horizontal position, the satellite slipped from the Turn-Over Cart (TOC) and fell to the floor (see Figure 3-1). The satellite sustained heavy damage (see Figure 3-2), although no injuries to personnel occurred. The exact extent of the hardware damage is still being assessed.

The operation scheduled for that day was to shim the Microwave Humidity Sounder (MHS) instrument by removing and replacing the instrument. This operation required the spacecraft to be rotated and tilted to the horizontal position using the TOC. The spacecraft fell to the floor as it reached 13 degrees of tilt while being rotated. The reason was clear from inspection of the hardware: *the satellite fell because the TOC adapter plate was not secured to the TOC with the required 24 bolts* (see Figure 3-3).

Three days after the mishap, on September 9, 2003, Dr. Ghassem Asrar, NASA Associate Administrator for Earth Science established the NOAA N-PRIME Mishap Investigation Board (MIB) in the public interest to gather information, conduct necessary analyses, and determine the facts of the mishap. To identify the root causes at work in the NOAA N-PRIME Mishap, the MIB undertook two approaches. The first was an extensive analysis of the sequence of events prior to and on the day of the mishap; the planned operational scenario vs. the actual execution; and the planning activities, including scheduling, crew assembly and test documentation preparation (see Section 5 – Description of Events Leading to Mishap). The second approach was to utilize the Human Factors Analysis and Classification System (HFACS) (2000) to provide a comprehensive framework for identifying and analyzing human error (see Section 6 – Method of Investigation and Section 7 – Findings). Evidence from a number of sources, including witness interviews, test and handling procedures, and project documents, were used to develop the accident scenarios and populate the HFACS model.

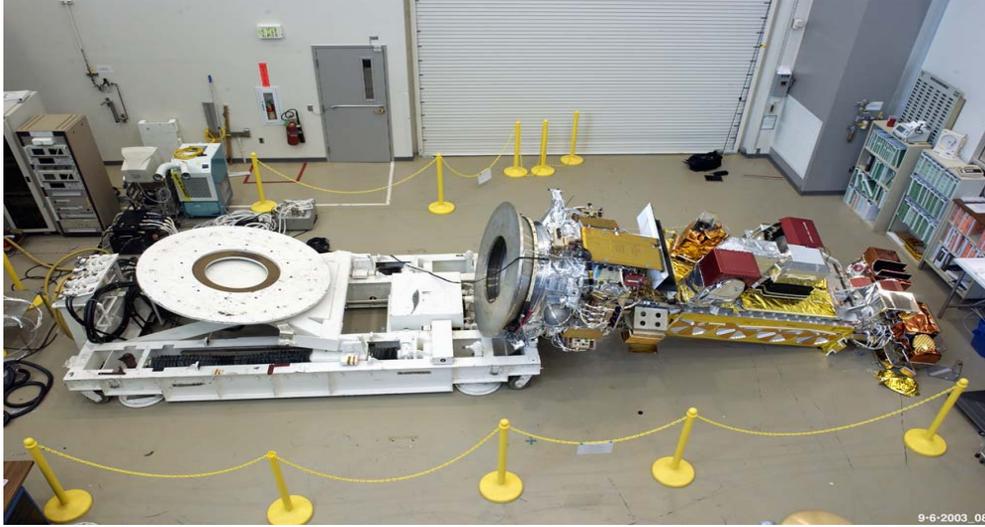


FIGURE 3-1: NOAA N-PRIME FELL OFF THE TURNOVER CART

Figure 3-1: NOAA N-PRIME FELL OFF THE TURN OVER CART



Figure 3-2: NOAA N-PRIME DAMAGES

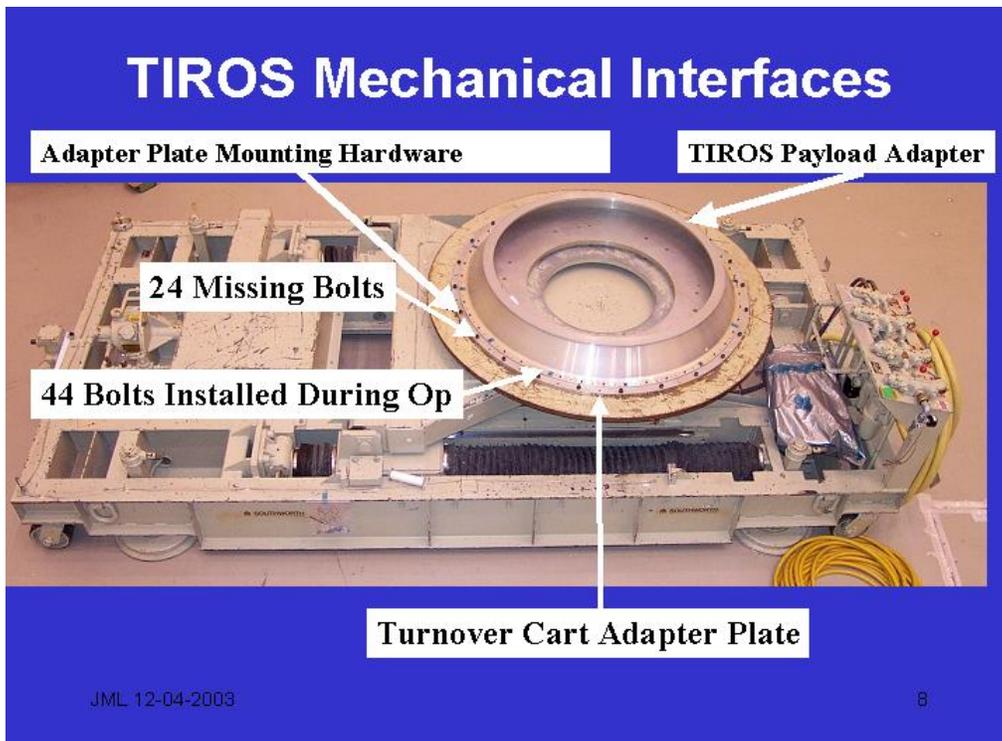


Figure 3-3: TURN OVER CART INTERFACES

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The causes of the NOAA N-PRIME mishap are summarized below. More detailed findings are provided in Section 7.

***Proximate Cause:** The NOAA N-PRIME satellite fell because the LMSSC operations team failed to follow procedures to properly configure the TOC, such that the 24 bolts that were needed to secure the TOC adapter plate to the TOC were not installed.*

The root causes are summarized below along the four levels of active or latent failures as ascribed by the HFACS framework.

*The TOC adapter plate was not secured to the TOC because the LMSSC operations team failed to execute their satellite handling procedures.*

The Responsible Test Engineer (RTE) did not “assure” the turnover cart configuration through physical and visual verification as required by the procedures but rather through an examination of paperwork from a prior operation. Had he followed the procedures, the unbolted TOC adapter plate would have been discovered and the mishap averted. Errors were also made by other team members, who were narrowly focused on their individual tasks and did not notice or consider the state of the hardware or the operation outside of those tasks. The Technician Supervisor even commented that there were empty bolt holes, the rest of the team and the RTE in particular dismissed the comment and did not pursue the issue further. Finally, the lead technician and the Product Assurance (PA) inspector committed violations in signing off the TOC verification procedure step without personally conducting or witnessing the operation. The MIB found such violations were routinely practiced.

*The LMSSC operations team’s lack of discipline in following procedures evolved from complacent attitudes toward routine spacecraft handling, poor communication and coordination among operations team, and poorly written or modified procedures.*

It is apparent to the MIB that complacency impaired the team directly performing the operation and those providing supervision or oversight to this team. The operation was consistently characterized as routine and low risk, even though it involved moving the spacecraft. Several other adverse mental states, including fatigue and external constraints that limited the availability of portions of the crew to a half day, also may have had roles in the mishap. Incomplete coordination concerning ground equipment use and status, and late notification of operation schedules exacerbated the lack of rigor in handling operations. Standard operating procedures contained ambiguous terminology (e.g., “assure”) and can be significantly modified using redlines for unique (one time only) operations. These practices were the preconditions or latent failures that promoted the mishap occurrence.

*The preconditions within integration and test (I&T) operations described above existed because of unsafe supervision practices within the LMSSC project organization, including ad hoc planning of operations, inadequate oversight, failure to correct known problems, and supervisory violations.*

## NOAA N-PRIME Mishap Investigation-Final Report

The RTE and I&T manager failed to provide adequate supervision and repeatedly violated procedures when directing and monitoring their operations crews. Waiving of safety presence, late notification of government inspectors, poor test documentation, and misuse of procedure redlines were routinely permitted. Further, the MIB believes that planning for the lift/turnover operation was hurried and resulted in a hastily formed operations team. Although all team members were experienced and competent, this atypical mix of authority among the various roles created dynamics that were not conducive to open discussion and shared responsibility. The MIB concludes that the lack of enforcement and support by the supervisory chain concerning the roles and responsibilities of the operation team members and the hurried planning for this operation are factors in this mishap.

*The unsafe supervision practices within the TIROS program had their roots in the LMSSC organization: the inadequate resources and emphasis provided for safety and quality assurance functions; the unhealthy mix of a dynamic I&T climate with a well-established program and routine operations; and the lack of standard, effective process guidelines and safeguards for operations all negatively influenced the project team and activities.*

The MIB finds the LMSSC system safety program to be very ineffective. Few resources are allocated to system safety, few requirements for safety oversight exist and little programmatic supervision was provided for the safety representatives. The I&T environment within the TIROS program is engendered by routine operations for which schedules and specific activities are frequently optimized. Such an environment requires rigorous oversight and processes to prevent overconfidence and complacency. The MIB believes that LMSSC failed to provide the organizational safeguards to prevent this and other potential mishaps, especially in key areas that regulate operational tempo, operations planning, procedure development, use of redlines, and Ground Support Equipment (GSE) configurations.

*The in-plant government representation, Defense Contract Management Agency (DCMA), and the GSFC Quality Assurance (QA)/safety function failed to provide adequate oversight to identify and correct deficiencies in LMSSC operational processes, and thus failed to address or prevent the conditions that allowed the mishap to occur.*

The in-house Government Quality Assurance Representative (QAR) (acting as a DCMA agent) inappropriately waived a Mandatory Inspection Point during the Saturday morning operation. Although his presence may not have prevented the mishap, the MIB believes this waiver is indicative of a failed oversight process and barrier. The MIB finds that the government quality assurance and safety oversight at GSFC were also deficient, having become issue driven due to the maturity of the project. Once issues were brought to their attention, the QA/safety personnel worked their resolution but there was very little proactive oversight, audit, inspection, etc. of the LMSSC operations. The in-house Government QAR knew of some of the problems associated with procedure discipline and safety and program assurance oversight but did not communicate them to the NASA project. Given the prevalence of some of the contractor deficiencies identified in this investigation, however, it is the MIB's assessment that the government in-plant representative, DCMA, and the GSFC QA/Safety function should have identified and demanded correction for these deficiencies.

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*The Government's inability to identify and correct deficiencies in the TIROS operations and LMSSC oversight processes were due to inadequate resource management, an unhealthy organizational climate, and the lack of effective oversight processes.*

Relative to resource management, the GSFC project, in working to deal with a declining workload and resources, allowed and even encouraged trade-offs between the schedules, staffing and milestones for the two remaining satellites in the Polar Operational Environmental Satellite (POES)/(TIROS) project. These constant and rapid trade-offs exacerbated the already fast operational tempo of the LMSSC I&T team. Organizational climate was found to be an issue, primarily in the government on-site structure. There is no Project in-plant civil servant government presence. The Project in-plant government representatives (one in quality assurance, two in I&T) were past employees of LMSSC and were hired as outside contractors by the GSFC Project. The MIB believes that their past associations with the company might precipitate undue complacency due to familiarity. Although the POES Project and the contractor track and trend closure of contractor generated Non-Conformance Reports (NCRs) for timeliness, there is no process in place to analyze and trend NCRs for cause and to identify systemic problems. The MIB found no effective process in place to follow up on closure of Defense Contractor Management Agency (DCMA) generated Corrective Action Requests (CARs). Supplier Assurance Contract (SAC) generated audit deficiencies, and action items from an external review (TIROS Anomaly Review). Likewise lacking is the government organizational oversight to monitor, verify, and audit the performance and effectiveness of the I&T processes and activities.

The MIB found the DCMA CAR assessment and reporting process and other DCMA audit processes to be deficient in identifying troubling trends in the LMSSC facility. Review of CARs indicates repeated requirement violations and bypassing of Mandatory Inspection Points by the contractor. The DCMA Technical Assessment Group (TAG) facility audits, the DCMA annual safety audits, and the DCMA facility summary reports of CARs prior to the mishap, however, all indicated a healthy facility environment, with no noteworthy problems reported.

MIB recommendations to correct the findings/deficiencies above are provided in section 8 - Recommendations.

It is the MIB's assessment that many of the findings uncovered in this mishap investigation are not specific to this mishap but are systemic in nature. A separate follow-up investigation should be conducted to further examine and characterize these systemic problems.

## SECTION 4

### PROGRAM DESCRIPTION

At the beginning of 1960, the United States had two credible space agencies – National Aeronautics and Space Administration (NASA) and Department of Defense (DOD). Each was pursuing very broad space programs, including manned space flight. In this same time frame, President Kennedy announced the development of a new operational weather satellite program. The Environmental Sciences Services Administration (ESSA), the predecessor agency of the National Oceanic and Atmospheric Administration (NOAA), by the authorization acts of 1962, was given management and operations responsibilities. The world's first operational weather satellite, ESSA-1, was launched on February 3, 1966 and the second on February 28, 1966. NOAA's operational weather satellite service, now an environmental satellite service, continues today.

In 1973, a National Space Policy study, led by Office of Management and Budget, was undertaken to address the advantages of converging DOD and NOAA operational weather satellite programs. The 1973 review resulted in NOAA being directed to use DOD's Defense Meteorological Satellite Program (DMSP) Block 5D spacecraft, which had recently been awarded to RCA by DOD. NASA retained their role as spacecraft system manager and funded the development and launch of the first satellite in this new series, called TIROS-N, which was launched in 1978.

NOAA depends on NASA and DOD to procure and launch its spacecraft. The contracts for NOAA's satellites are let and administered by NASA. NOAA's polar orbiting satellites are launched from Vandenberg Air Force Base Facility. NOAA reimburses NASA and DOD for personnel and other costs incurred when helping NOAA meet its space mission objectives. NOAA is responsible for determining user requirements for satellite services, specifying the performance of the systems needed to satisfy these requirements, and obtaining the funds needed to build and launch the satellites and build and operate the ground segments of the systems.

NOAA assigns a letter to the satellite before it is launched and a number once it has achieved orbit. For example, NOAA M, the newest in the series, was launched on June 24, 2002 and is now called NOAA-17.

#### **Technical Mission**

The NOAA polar satellite program is built and operated to support the needs of the National Weather Service's global forecasting responsibility. Instruments have evolved over time. The most advanced of these satellite systems provide a suite of instruments for imaging and measuring the Earth's atmosphere, its surface, and cloud cover, including earth radiation, atmospheric ozone, aerosol distribution, sea surface temperature, vertical temperature and water profiles in the troposphere and stratosphere; measurement of protons and electron flux at orbit altitude. The key instruments on the satellite are: the Advanced Very High Resolution Radiometer (AVHRR), which detects energy in the visible and infrared portions of the Electromagnetic spectrum; the High Resolution Infrared Radiation sounder (HIRS/3), which

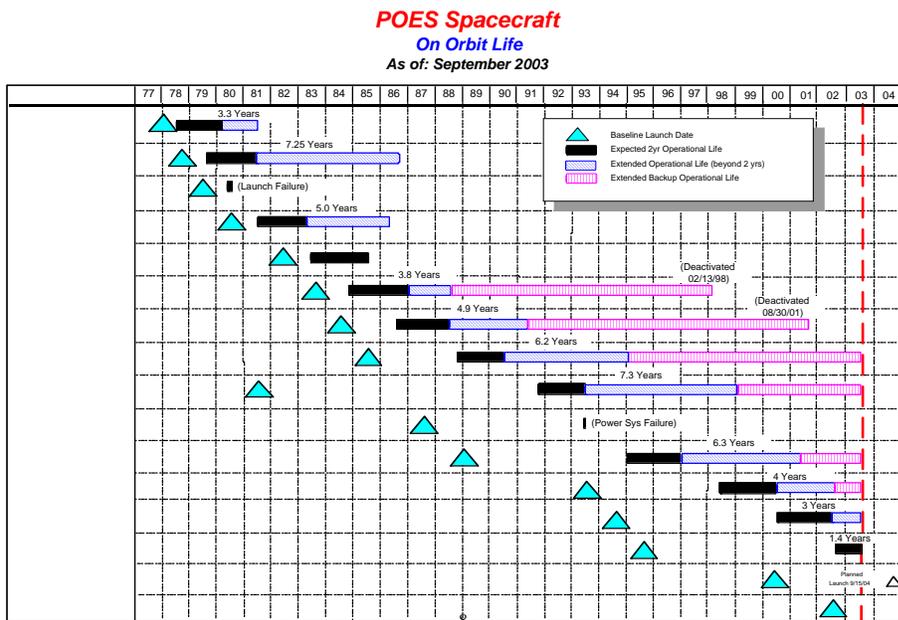
# NOAA N-PRIME Mishap Investigation-Final Report

provides the atmosphere's vertical temperature to about 40 km, ocean surface temperatures, total atmospheric ozone levels, precipitable water, cloud height and coverage, and surface radiance; and the Advanced Microwave Sounding Units-A/B, which measures scene radiance and there-by temperature and moisture. The satellites also support ozone monitoring and remote data collection and an international search and rescue program. Since 1982, this program is credited with saving more than 17,000 lives by detecting and locating emergency beacons from ships, aircraft, and people in distress.

## Project Management and Organization

### Contractor

The NOAA POES Program, based on TIROS-N design, has been flying since 1978. POES Satellite Launches are shown in Figure 4-1. Sixteen polar-orbiting, Earth observing satellites were built by RCA, and its successor organizations as it transitioned from RCA management to General Electric management, Martin Marietta management, and finally Lockheed Martin Space Systems Company (LMSSC) management using the DMSP spacecraft design. During these transitions in management, most of the spacecraft were built at the former RCA facility located at East Windsor, New Jersey.



An orbit constellation consists of a pair of satellites, which ensures that every part of the Earth is regularly observed at least twice every 12 hours.

Figure 4-1: POES Satellite Launches

Both of Lockheed's TIROS and DMSP Programs were relocated from East Windsor, New Jersey to Sunnyvale, California in 1998 as part of a planned consolidation of LMSSC Satellite integration and test (I&T) operations. Collocating TIROS and DMSP I&T operations with other satellite I&T operations to the LMSSC Sunnyvale facility was intended to create some efficiency in an era of dwindling Defense and commercial business. The last two spacecraft in the POES

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Program (NOAA N and N-PRIME) were largely built and integrated at the Sunnyvale, California facility. Many spacecraft subsystems were actually manufactured in the East Windsor facility and shipped with their associated support equipment to Sunnyvale, while other subsystems had their manufacturing and testing completed in Sunnyvale. Prior spacecraft in the TIROS series were manufactured, integrated, and tested in the East Windsor, New Jersey facility. DMSP finished production of the final five satellites in their series prior to closure of the East Windsor facility. Many of the personnel associated with the long history of the TIROS program did not relocate to the Sunnyvale operation.

The last two of the Television Infrared Observational Satellites (TIROS) series spacecraft, NOAA N and N-PRIME are in final stages of testing at LMSSC under the Polar Operational Environmental Satellite (POES) program. LMSSC is also under contract to the Department of Defense (DOD) for the development, test and launch of the remaining Defense Meteorological Satellite Program (DMSP) series spacecraft, of which three are at various stages of testing at the Sunnyvale plant. The DMSP and NOAA spacecraft are located in adjacent integration and test facilities and the programs share a common ground support equipment (GSE) storage area.

The TIROS Program organization at Lockheed is shown in Figure 4-2. TIROS is managed by the Program Manager who reports directly to the Vice President of Civil Space Programs.

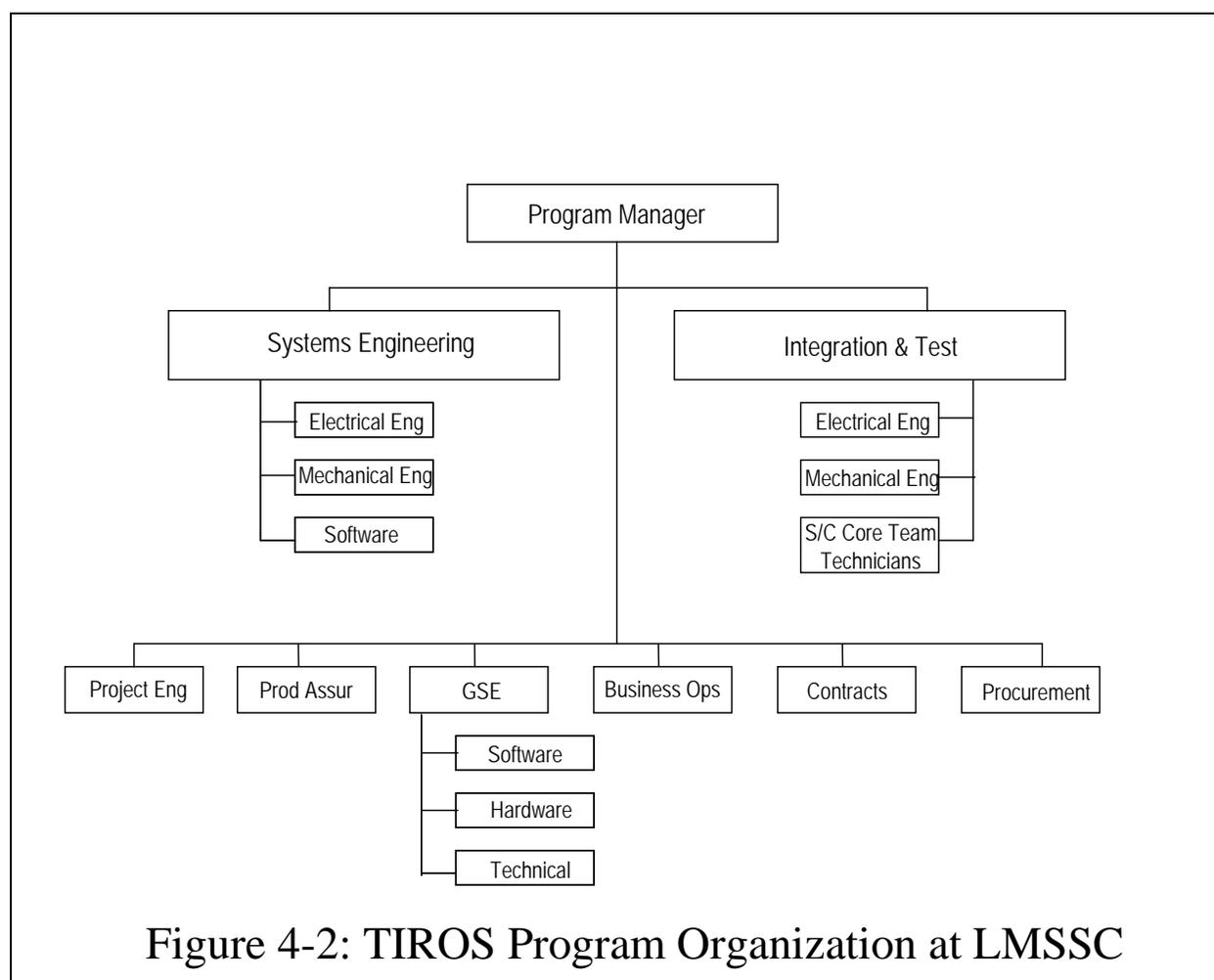


Figure 4-2: TIROS Program Organization at LMSSC

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The Program Manager is fully responsible for all activities on TIROS including interfacing with NASA, program planning, controlling program changes, providing resources, developing and allocating the budget, reviewing and reporting on program performance, and executing the terms and requirements of the cost plus award fee contract. The Program Manager is supported by a senior staff of technical and business managers who provide oversight for the daily activities of the program. The Systems Engineering Manager, supported by a staff of electrical, mechanical and software engineers, is responsible for spacecraft test and storage support, launch team readiness, meeting support, verification engineering, and instrument interface management. The Integration and Test Manager, supported by a staff of electrical and mechanical engineers and technicians, is responsible for buildup of the satellite, environmental testing, and launch flow. The Ground Support Equipment Manager, supported by a staff of electrical and software engineers and technicians, is responsible for maintenance and repair of existing and new equipment required to support I&T and launch site operations. Other senior staff members reporting directly to the Program Manager are Project Engineering, Product Assurance, Procurement, Business Operations, and Contracts Administration.

### Government

The Polar Operational Environmental Satellites program falls under the NASA Headquarters Office of Earth Science (Code Y) which delegates the POES mission to GSFC. At GSFC, the POES Project is part of the Geostationary Operational Environmental Satellite (GOES)/POES Program in the Flight Programs and Projects Directorate. POES is a fully reimbursable project to NOAA.

The scope of the POES Project at the time of the mishap was the completion and launch of NOAA N in September 2004; the completion, several year storage, and launch of NOAA N-Prime in March 2008; the completion of instrument integration into the European MetOp-1 satellite, storage and launch support of MetOp-1 in 2009; the completion of instrument integration into MetOp-2 and launch support in 2005 of MetOp-2; and the completion of instrument integration into MetOp-3 and storage until 2010 (launch in 2014 is beyond the POES completion date of 2010). The POES Project held the POES spacecraft contract with Lockheed Martin, instrument contracts with Ball Aerospace, Northrop Grumman and ITT. NASA KSC had the NOAA N and NOAA N-PRIME launch vehicle contracts with Boeing. NOAA provided foreign instruments and had an instrument contract with General Electric (GE) Panametrics.

The estimated cost for the development and launch of 16 satellites (NOAA-A through NOAA N-Prime) including instruments, launch vehicles, and three sets of instruments for MetOp through 2010 is \$2.2B. These costs do not include NOAA's costs to operate the satellites or its costs to provide the science processing. The total cost expended by NASA through fiscal year 2003 on the NOAA N-PRIME spacecraft, the one involved in the current mishap, is estimated at \$223 million dollars.

POES PROJECT: The POES Project organization is shown in Figure 4-3. The POES Project is managed by the Project Manager who is fully responsible for all activities on the project including interfacing with NOAA, program planning, resources, developing and allocating the

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budget, executing and overseeing the program plan, controlling program changes, and reviewing and reporting program performance. The Deputy Project Manager, a senior member of the management team, serves as the Project Manager when the Project Manager is unavailable. The Deputy Project Manager for Resources directs all the business aspects of the project including financial, budget, configuration management, scheduling, library, and Information Technology (IT).

The Observatory Manager is responsible for spacecraft development and serves as the Contracting Officer's Technical Representative for the Lockheed Martin contract. The Instrument Systems Manager is responsible for the development of the U.S. instruments and their delivery to Lockheed Martin and the MetOp program. The Flight Operations Manager is responsible for interfacing to the NOAA satellite operations and launch vehicle integration. The System Assurance Manager is from the GSFC Office of Systems Safety and Mission Assurance and is responsible for product assurance. The NOAA Liaison Office is staffed by NOAA engineers resident at GSFC providing continual interface to NOAA. Procurement support is provided by the GSFC Management Operations Directorate. Support staff includes financial managers, instrument managers, spacecraft engineers, and a part time Project Scientist.

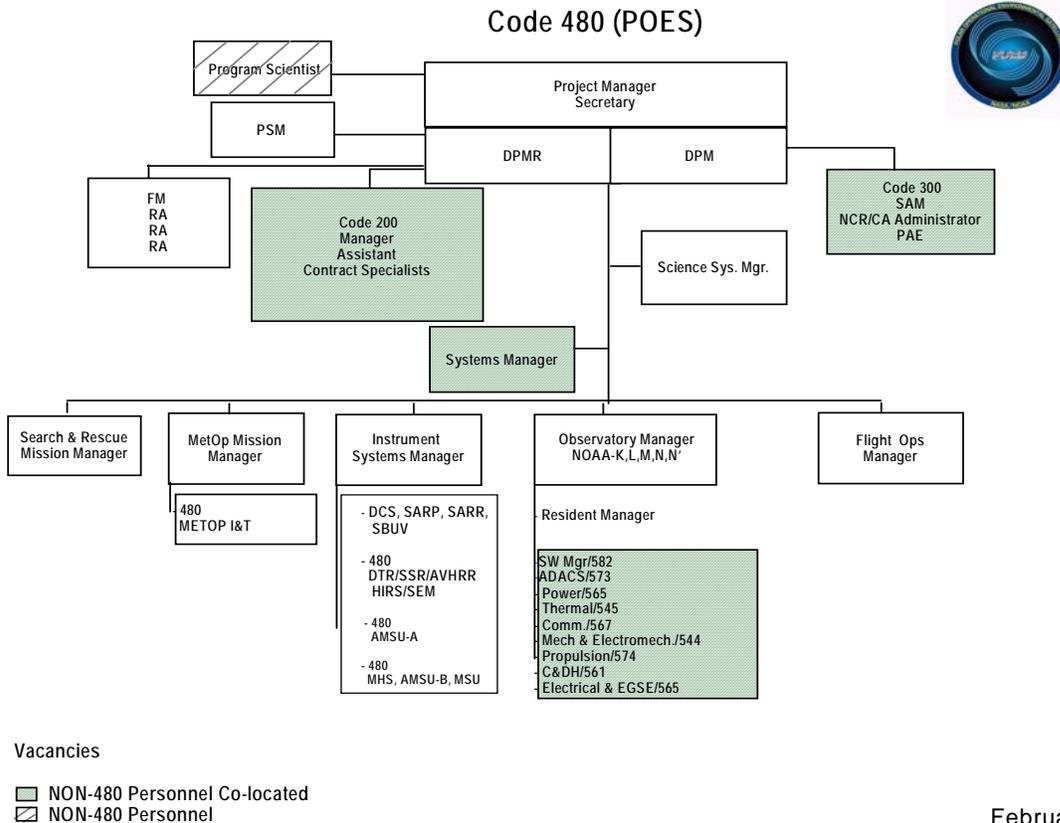


Figure 4-3: POES Project Organization at NASA-GSFC

## NOAA N-PRIME Mishap Investigation-Final Report

NOAA: NOAA has over-all responsibility for the POES Program by providing the funding for the procurement of the satellites, as well as in operating, maintaining and processing the data from them once they are launched. Over-all program management and planning for the satellites in NOAA is led by the Office of Systems Development, which is part of the National Environmental Satellite Data and Information Service (NESDIS). To ensure effective communication of requirements, and to address issues relating to schedules, satellite technical performance and budgetary considerations, NOAA maintains a Liaison Office at Goddard Space Flight Center, which is co-located with the POES Project. The Polar Acquisition Manager, along with a small staff of engineers, monitor the progress of the satellite developments and address technical issues, such as potential performance waivers, and coordinates any necessary review of such issues within NOAA as information is required by the NASA POES Project. The Liaison Office personnel participate in most contractor reviews but do not have direct oversight of the NASA Contractors or over any other NASA personnel. They do participate as members of NASA’s Performance Evaluation Boards for POES instrument and satellite contracts for which award-fee evaluations are performed. Per the Memorandum of Understanding (MOU) between NASA and NOAA for the POES Program, a formal exchange of updated requirements and budgetary information is performed twice yearly. The NOAA Liaison Office is shown in the organization chart in Figure 4-4.

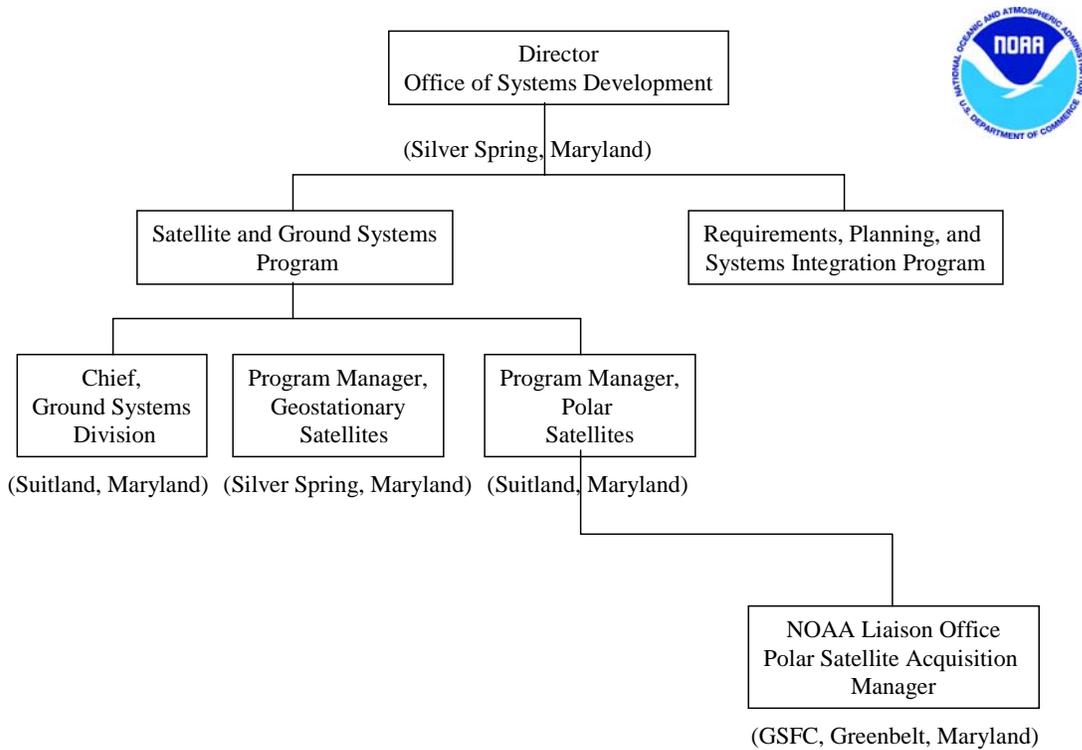


Figure 4-4: NOAA POES Program Personnel at NASA/GSFC.

## SECTION 5

### DESCRIPTION OF EVENTS LEADING TO MISHAP

On Saturday, September 6, 2003, during an operation that required repositioning (rotating) the TIROS NOAA N-PRIME spacecraft from a vertical to a horizontal position, the spacecraft slipped from the Turn-Over Cart (TOC) and fell to the floor. The spacecraft fell because the TIROS adapter plate to which it was mounted was not bolted to the TOC adapter plate with the required 24 bolts. The bolts were removed from the TOC by another project while the cart was in a common staging area, an activity which was not communicated to the NOAA project team.

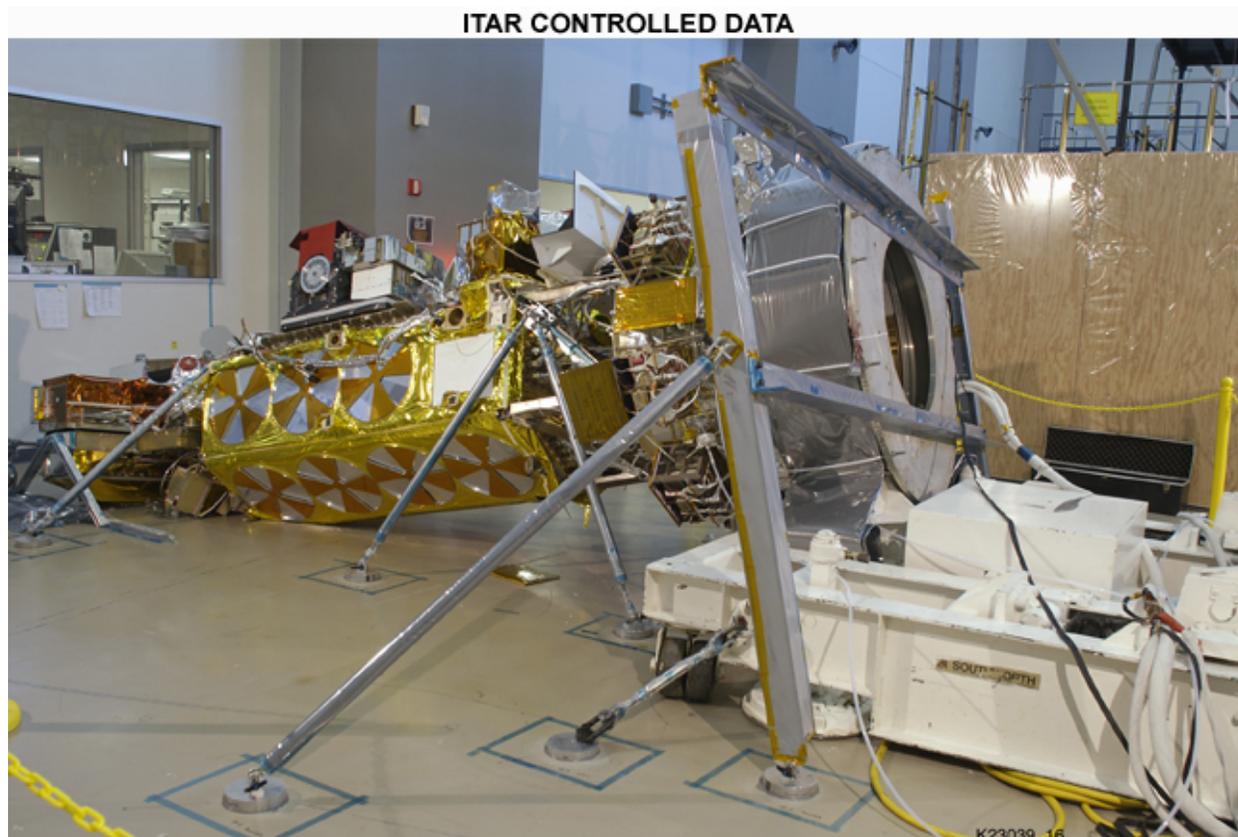
The operation scheduled for that day was to shim the Microwave Humidity Sounder (MHS) instrument by removing and replacing the instrument on the spacecraft. This operation required the spacecraft to be rotated and tilted to the horizontal position using the TOC. The operation involved preparing the spacecraft and TOC, installing the spacecraft on the TOC, and tilting the spacecraft to the horizontal position. After that, the MHS Instrument would have been removed and reinstalled.

The plan to perform this activity on Saturday began on Wednesday, September 3. The document authorizing the MHS Shimming activity, Program Directive (PD) PD 03-58F-D2805, was initiated on Wednesday, and the Program Office at Goddard Space Flight Center (GSFC) was informed during a routine telecon on Friday, September 5. The paperwork providing detailed instructions for the operation was developed from the PD and included a single, hand-entered instruction in the Log of Operations (LOO) and four (4) hand-entered, redlined steps in the Instrument procedure, TI-MHS-3278200 "MHS Installation / Removal." The four (4) redlined steps violated rules for the use of redlines, but were never-the-less approved by the LMSSC Responsible Test Engineer (RTE) and Quality Engineering (QE).

The RTE, a lead technician (PQC), a technician, and the Technician Supervisor (acting as a technician equivalent) conducted the operation. The Product Assurance (PA) inspector, often referred to as "QA", joined the operation in progress, thereby missing the key TOC preparation and configuration assurance activity. He stamped off the procedure without actually witnessing or visually inspecting the TOC configuration. The required Government Quality Assurance Representative (QAR or Customer Representative) was not present, nor was the required LMSSC safety representative. The TIROS (NOAA) acting Integration and Test (I&T) Manager was present as an observer during the actual spacecraft lift, but was not in the high-bay during preparations for the spacecraft lift, nor at the time of the mishap.

The activity proceeded as planned through the installation of the spacecraft on the TOC, and was rotated about the vertical axis to align the instruments in the desired clock position. As the spacecraft reached 13 degrees of tilt from the vertical while being rotated to the horizontal position, it slipped off the TOC and fell approximately three (3) feet to the floor, tipping over in the process. Immediately following the mishap, the Technician Supervisor notified the I&T manager who then notified his management. The fallen spacecraft was "safed" to prevent further damage and to protect personnel and the co-located NOAA N spacecraft (the Nickel-Cadmium

batteries were fully charged, the propulsion system was pressurized, and the separation band was tensioned. (Figure 5-1: NOAA N-PRIME Safed)



**Figure 5-1: NOAA N-PRIME Safed**

This section describes the details of the actual incident, events leading up to the incident, and details describing the operating situation. Since the inter-relationship of many factors leading to this incident is complex, no single subsection or discussion can properly establish the specific cause. Missed Opportunities are identified throughout the discussion, and are summarized in Section 5.6, Summary of Missed Opportunities. Specific discussion of causal factor is included in Section 7. This section (Section 5) lays the groundwork for later more detailed analysis of each of the contributing factors:

Section 5.1 Planned Operation

Section 5.2 Planning and Procedures (including the scheduling, crew, assembly and test documentation preparation activities.)

Section 5.3 Crew Makeup

Section 5.4 Turnover Cart (TOC)

Section 5.5 Day of the Mishap.

Section 5.6 Root Cause Analysis

Section 5.7 Summary

The primary mishap analysis was performed using the Human Factors Analysis and Classification system (HFACS) to identify, analyze, and classify the human errors. (See Sections 6 and 7) In addition, Root Cause Analysis diagrams were developed as a cross-check and are provided in Appendix E.

### **5.1 Planned Operation**

The planned operation consisted of:

1. preparing the TOC that had been utilized recently for a NOAA N spacecraft operation but subsequently stored in a support equipment storage area common to two programs;
2. preparing the NOAA N-PRIME spacecraft for installation on the TOC;
3. lifting the spacecraft onto the TOC and securing its conical payload (booster) adapter to the TIROS adapter plate;
4. and finally, rotating the TOC with the spacecraft attached from the vertical to the horizontal position.

The operation had been originally scheduled to begin the following Wednesday but was moved forward 3 working days to Saturday to take advantage of a schedule opportunity. The preparations required for the TOC and the spacecraft were likewise accelerated. This change in schedule played a role in the preparation activities.

The operation on Saturday morning proceeded according to the following steps:

1. Final preparations were made to the spacecraft, including removal of the work stands around the spacecraft and repositioning of the spacecraft within the high bay.
2. The newly modified spacecraft vertical lifting sling was installed to the crane and then attached to the spacecraft.
3. The spacecraft was detached from its handling cart and lifted high enough to permit moving the TOC under the suspended spacecraft.
4. The spacecraft was lowered onto the TOC, 44 of 88 attachment bolts installed and torqued, and the lifting fixture detached from the spacecraft.
5. The spacecraft was then to be rotated about its vertical axis to position the side-mounted instrument package, including MHS, such that it would be facing upward after the spacecraft was rotated to the horizontal position.
6. Rotation of the spacecraft toward the horizontal position was begun.

The planned final configuration is represented in the photograph of NOAA N shown in Figure 5-2: NOAA N Spacecraft in Horizontal Position on TOC.

A summary of the actual timing of the events is shown below in Figure 5-3: Timeline (Simplified)– Saturday Operation, and Table 5-1: Operation Event Timeline, and with greater detail in Section 5-5.



Figure 5-2: NOAA N Spacecraft in Horizontal Position on TOC

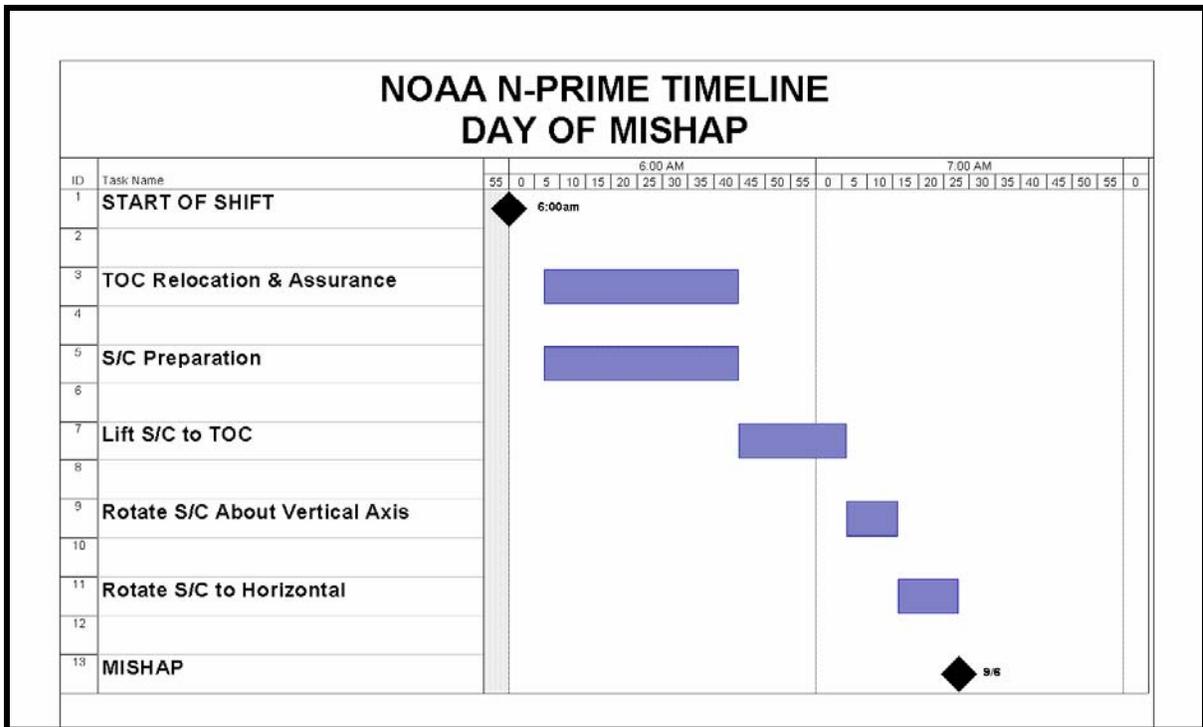


Figure 5-3: Timeline (Simplified)– Saturday Operation

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<b>6:00-6:45 am</b>	Between 6:07am and 6:13 am, the RTE, Technician Supervisor, I&T Manager, and two technicians arrived. The PA arrived at 6:42 am. NASA QAR was notified at home at about the 6:30 am time frame, but his first entry into the High Bay did not occur until 8:25 am. LMSSC safety was not notified of this operation at all.
<b>6:07-6:45 am</b>	The TOC was moved from the common staging area (Ante Room) into the NOAA High Bay and prepared to support the NOAA N-PRIME activity. These activities were completed prior to 6:45am. The cart was prepared by the lead technician (PQC), and signed off in the procedure by the PQC, RTE, and PA, signifying that the TOC was “assured” of proper configuration per procedure (TI-MH 3278200). (At this point, the PQC, RTE, and PA should have recognized that the TOC was not properly configured and then should have proceeded to properly configure the TOC by installing the 24 attachment bolts.)
<b>6:45-7:06 am</b>	The spacecraft was lifted and secured to the TOC.
<b>7:06-7:16 am</b>	The spacecraft was rotated 180 degrees about the vertical axis while still in the vertical configuration.
<b>7:16-7:28 am</b>	The spacecraft was rotated from the vertical to the horizontal position. As the spacecraft reached about 13 degrees of rotation, it slipped off the TOC and fell to the floor.

**Table 5-1: Operation Event Timeline**

The newly modified spacecraft vertical lifting sling, to be used for only the second time, would be installed to the crane, then attached to the spacecraft, and the spacecraft detached from its handling cart and lifted high enough to permit moving the TOC on its air bearing jacks under the suspended spacecraft. The lifting sling modification reduced the required number of technicians to attach and remove the sling from the spacecraft from seven (7) to four (4), reducing the number of technicians working around the spacecraft, but has no other significance to this operation because their sole task was to hold tag lines to keep the lifting sling legs away from the spacecraft during the sling attach/detach operation.

Once positioned, the spacecraft would be lowered onto the TOC, 44 of 88 attachment bolts installed and torqued, and the lifting fixture detached from the spacecraft. (Note: The installation of every other bolt attaching the TIROS flight adapter to the TIROS TOC Adapter was common practice, and in fact is common throughout the aerospace industry because the handling stresses and loads are minor compared to the flight loads the interfaces are designed to accommodate. (Its significance is relative to a discussion of ‘empty bolt holes’, which is included later in the investigation analysis.)

The spacecraft would then be rotated about its vertical axis to position the side-mounted instrument package, including MHS, such that it would be facing upward after the spacecraft was rotated to the horizontal position. This rotation was standard practice but is not included in the procedures or planning paperwork.

The spacecraft fell to the floor as it reached 13 degrees of tilt while being rotated from vertical to horizontal. It is clear that the spacecraft fell because the TOC adapter ring was not secured to the

TOC with the required 24 bolts. (Proximate Cause)

### 5.2 Planning and Procedures

The operation was planned during the period from Wednesday, 3 September 2003, through Friday, 5 September 2003. (Figure 5-4: Timeline for Wednesday -Friday Preparations)

On Wednesday, September 3, the NOAA N-PRIME MHS Shimming activity schedule was moved ahead from the initial plan to begin on September 10 to the updated plan to begin on September 6, the date of the mishap. Some of the preparation work on the flight spacecraft, such as tensioning the V-band, actually began on Friday, September 5. This short-notice advance in the schedule date had several consequences. The TOC required repair to remove a red tag, leading to a repair that was acceptable but required a subtle change in how the spacecraft was mated to the TOC. In addition, technicians were requested to perform operations on the flight spacecraft without released paperwork, leading to dissention among some of the NOAA I&T Team, and resulting in at least one key team member not working on Saturday. The accelerated pace may have led to less communication between the two programs sharing the TOC. Each of these factors is discussed in more detail in later sections.

The following paragraphs describe the authorizing paperwork, the change in schedule, and the redlined procedures for Saturday’s operation.

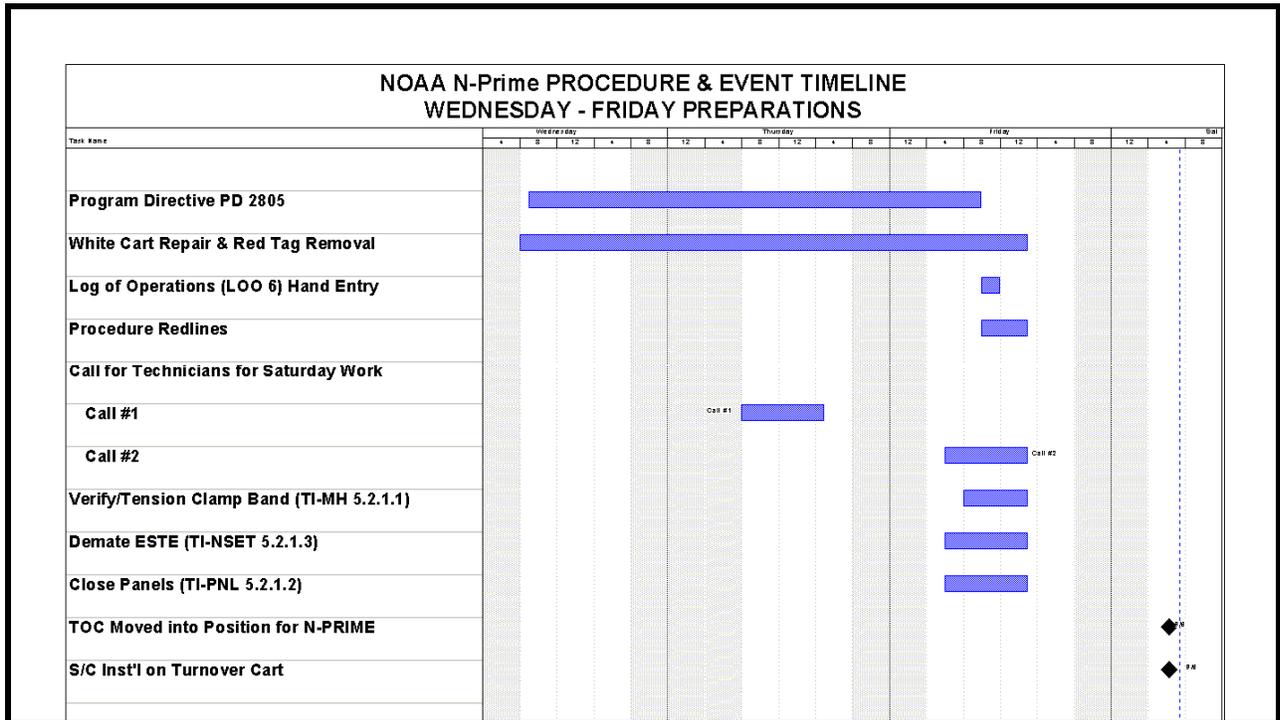


Figure 5-4: Timeline for Wednesday – Friday Preparations

### 5.2.1 Change in Schedule

A problem with the originally scheduled activity for Saturday, September 6 on the NOAA N spacecraft resulted in moving the MHS Shimming activity, and hence the S/C hoisting and turnover activity, forward from Wednesday, September 10, to Saturday, September 6. The original NOAA N-PRIME activity on Saturday involved the Electrical Team, not the Mechanical Team, resulting in a late call for technician support for the activity. Discussions with LM and GSFC Project/Program personnel also indicated there was a desire to keep the spacecraft team busy and productive during the NOAA-N downtime.

The team for Saturday was hastily assembled, with the first call for mechanical technician support for the NOAA N-PRIME activity made on Thursday, September 4, indicating a very late decision to move the activity date forward. This accelerated schedule created an environment where the technicians were requested to perform activities on the flight spacecraft without approved paperwork, causing dissention among certain team members. This led to at least one key crewmember not participating in the Saturday operation and resulted in a briefing to NOAA I&T personnel on Friday on the need to work with approved paper and procedures. The project schedules published on September 3<sup>rd</sup> and 4<sup>th</sup> were never updated to indicate the new schedule. (Figures 5-5: TIROS N-PRIME Daily Schedule 9/03/2003 and 5-6: TIROS N-PRIME Daily Schedule 9/04/2003,)

The Program/Project had an opportunity to save schedule and costs by performing the pending Electromagnetic Compatibility (EMC) testing on the two spacecraft, NOAA N and N-PRIME, back-to-back. The test setup is somewhat complex, and significant savings could be realized if the back-to-back testing could be accomplished. This contributed to the decision to work Saturday, even though the originally planned activity could not be performed.

The need to repair the red-tagged TOC was also accelerated, and led to a subtle change in the way the S/C and TOC were positioned for the actual mate. The TOC was maneuvered under the hanging S/C, instead of the procedure-directed crane movements to maneuver the spacecraft into position as it was being lowered. This change is not noted in the procedure, but it is not deemed significant.

### 5.2.2 Program Directive and LOO

Tasks on the TIROS NOAA program are authorized by the Program Office at GSFC via a Program Directive (PD). The document authorizing LMSSC to perform the MHS Shimming activity, Program Directive (PD) PD 03-58F-D2805, was initiated on Wednesday, September 3, with final approval occurring on Friday, September 5. LMSSC generates a Daily Schedule, which details activities on each of the TIROS NOAA spacecraft. These schedules are updated periodically, but not necessarily daily. The activity to perform MHS Shimming first appears on the NOAA N-PRIME Daily Schedule dated Wednesday, September 3, 2003, with the date of the activity planned for Wednesday, September 10 through Tuesday, September 23, identifying the task as "MHS shim/penalty test". (Figure 5-5: TIROS N-PRIME Daily Schedule 9/3/03) This is consistent with the initiation of the PD on Wednesday, and provided a reasonable time to prepare for the activity the following Wednesday. Thursday's Daily Schedule, 9/4/2003, shows the same

planning date of September 10 for the activity. (Figure 5-6: TIROS N-PRIME Daily Schedule 9/4/03.) The first two tasks of that sequence, “Close Panel 1” and “Hoist S/C to Turnover Cart/Tilt to Horizontal”, were originally scheduled for Wednesday and Thursday, September 10 and 11.

The LM paperwork authorization system flows from the PD to a Log of Operations (LOO). (Figure 5-7: Paperwork Relationships (Ref: ITOP-509 SV, LEO-MET Integration and Test Operations Rev A, dated 7/26/00).

The LOO details the sequence of activities on a spacecraft flow, and describes the sequence that various operations are intended to occur. The new activity to perform the MHS Shimming was hand entered into the LOO (LOO 006) on September 5, but does not indicate the planned date for the activity. This is consistent with the preparation and approval dates of September 3 through 5.

From the LOO, the next level of documentation is either an Operations Order (Op Order) or a Technical Instruction (TI). An Op Order is normally used to specify a detailed procedure (sequence of steps) for an operation that will not be repeatedly performed. A TI is used for detailed sequences of steps that will be performed repeatedly. The NOAA N-PRIME use of the LOO and TI's is in accord with LM requirements, with the exception that critical detailed steps were redlined into the TI without the prescribed review and approval.

### 5.2.3 Redline Use to Create New Procedure

Proprietary Information

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#### 5.2.4 Procedure Review and Approval

Proprietary Information

#### 5.2.5 Inconsistent Approach to Hazard Identification

Proprietary Information

### 5.3 Crew Makeup

The crew makeup for the Saturday operation was comprised of experienced personnel, but as a direct result of the late decision to move the NOAA N-PRIME MHS shimming activity ahead in the schedule, the crew makeup was not optimum. Technicians had been requested to perform preparation work on the flight spacecraft without approved paperwork, such as tensioning the V-Band securing the spacecraft to its flight payload adapter and closing spacecraft panels #1 and #4. (Note: it is normal procedure to leave the V-Band at a low tension to minimize the long-term stress in the band.) Concerns about such requests were addressed on Friday by supervision calling an all-hands meeting to reiterate the company policy regarding work on flight spacecraft. This discussion occurred very late in the preparations for the rescheduled Saturday work and contributed to the difficulty in assembling a crew for the lift and turnover activity. Specifically, this concern led to one very experienced individual declining to participate in the Saturday activity. The Technician Supervisor filled in as a Technician Equivalent, permitted by LM Command Media when a full complement of technicians cannot be assembled. Also, some team members were notified as late as quitting time the day before the operation that they were to perform the next day. This created an atypical mix of authority among the various roles created dynamics that were not conducive to open discussion and shared responsibility. (Finding L-5, L-6, and L-11)

#### 5.3.1 Crew Experience

In spite of the dynamics leading up to the final crew selection, the experience of each member was extensive. (Table 5-2: Crew Experience) The large number of lifts and

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TOC operations that each crew member had experienced was probably the basis for almost all crew members commenting to the effect that, “This was just another routine operation.” This feeling is felt to have led to complacency being prevalent among the crew, and led to a lack of attentiveness and attention to detail.

Name	Previous Lifts	Previous TOC Ops	Previous TOC Configurations
I&T Manager	30	5	0
RTE	>25	8	8
Technician Supervisor / Technician Equivalent	75	4	0
Technician – Lead (PQC)	40	10	10
Technician (Shared W/DMSP)	75	25	25
PA (QA)	45	>20	10
	-----	-----	-----
<b>TOTAL OPERATIONS</b>	<b>290</b>	<b>72</b>	<b>53</b>

Ref: LMSSC Response to MIB 10-08-2003 AI-23 (with additional “TOC Configurations” info added by the MIB)

**Table 5-2: Crew Experience**

Of special note is the fact that the RTE and the Technician Supervisor were among the least experienced in the use of the Turnover Cart, but still had experienced a significant number of operations. The RTE was involved in eight (8) previous TOC configuration operations, but had always relied on the PQC for those operations to perform the configurations. That person was not working that Saturday. This experience mix may explain the miscommunication between the RTE and the Technician Supervisor in a conversation regarding the existence of empty holes with threads. The reference (by the Technician Supervisor) regarding empty bolt holes may have been toward the missing 24 bolts, but seems to have been interpreted (by the RTE) as referring to the 44 of 88 bolts in the payload adapter intentionally not installed. Even as the Technician Supervisor commented that there were empty bolt holes, the rest of the team and the RTE in particular dismissed the comment and did not pursue the issue further. (Finding L-2) In this instance, the Technician Supervisor lacked the knowledge to recognize the problem. The rest of the team, due to complacency and channelized attention, failed to pursue the apparent warning. **(MISSED OPPORTUNITY #1)**

An additional factor was that the RTE was planning on only ½ day support, as he had family related constraints for the afternoon. He had agreed to conduct the lifting and rotation activity, with another RTE taking over for the MHS shimming activity for the afternoon. Likewise the DMSP technician was scheduled to support another program on that day. This may have contributed to the fast pace of the operation, and may have influenced several decisions. (Finding L-4)

The I&T Manager decision to be present to observe the lifting activity is particularly

puzzling since he had significant lifting experience. The reason for his attendance was to observe the use of the newly configured lifting sling (requiring fewer technicians to attach and detach). The lack of procedure modifications to account for the change in crew size is indicative of the lack of importance placed on procedures. This is also indicative of both the lack of supervision discipline and the tolerance for inadequate procedure discipline and QA witness.

The experience of the Government QA Representative (QAR), substituting for the DCMA person specified in the procedure, was similar to the LMSSC technicians. He had witnessed the turnover operation at LMSSC 20-25 times, but had never witnessed the configuration of the Turnover Cart (installation of the adapter and its 24 bolts).

The TOC configuration activity does not require witness since it is GSE work, so it is not clear whether the TOC verification that was performed via paperwork versus actual inspection would have triggered a concern or not. However, the GSE configuration work does require LMSSC PA (QA) to buy off that the cart is properly configured. For this reason, it is not specifically felt that his non-presence early in the preparation was significant.

### 5.3.2 Crew Responsibilities

The following crew responsibilities are extracted from several sources, including the I&T Operations Practice and the Technical Instruction (procedure) being exercised. Some specific responsibilities of particular interest are:

- 1) Product Assurance Inspector: “Inspection shall verify that the test procedure has evidence of work performed and/or completed data entry. Verifications may be done either during or after the operation, as long as the operations and/or data readings can be verified.” (Ref: TI-MH 3278200 para 3.9.2)
- 2) Quality Engineer: “All test equipment, test setups, and collected data shall be subject to monitoring, review and validation by an authorized Quality Engineer (QE) per 326412. The signature or stamp of the cognizant QE shall indicate validation.” (Ref TI-MH 3278200, Para 3.9.)
- 3) Torque witness: “Shall be the cognizant mechanical integration technician or mechanical engineer.”

The following extractions expand on the above summaries:

The Responsible Test Engineer (RTE) is directly responsible for assuring adherence to the applicable safety requirements and safe conduct of the procedure. The RTE is also responsible for conducting a pre-operational safety briefing for all personnel involved in the test activity. The pre-operational briefing will include, but not be limited to, the following:

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- Safety items in operation/test, including safety-critical and hazardous operations as well as hazardous or toxic chemicals that will be used.
- Sequence of events and tasks.
- Job assignments for the tasks.
- Required safety equipment, if any, will be explained.

(Ref TI-MH 3278200, Para 3.3.1)

The RTE shall:

- Direct the operations of this procedure.
- Sign approval of performance data, as indicated in the procedure (e.g., RTE.)
- Generate TPCN's as required to incorporate test redlines.
- Annotate any out-of-sequence operations with an explanatory note on the applicable test procedure paragraphs.

Technicians:

- Technicians performing this procedure shall be assigned based on individual qualifications and the approval of the RTE.
- PQC stamps shall be applied to the test procedure or data sheets only as follows:
- At the designated points in this procedure as each task is completed (e.g., PQC\_\_\_\_\_).
- On all supplemental data sheets attached to this procedure.
- Adjacent to the last operation completed at the end of each work shift.

(Ref: TI-MH 3278200 para 3.9.2)

Torque witness:

- Shall be the cognizant mechanical integration technician or mechanical engineer.

Product Assurance Inspector:

- Check the calibration stickers on the test equipment to verify that calibration will remain current through the life of the test.
- Witness those operations steps that have a PA\_\_\_\_\_ entry, and shall verify acceptance of measurement and data recording of all performance data.
- Mandatory inspection verification paragraphs shall be indicated in the test procedure (e.g., PA\_\_\_\_\_). Inspection shall verify that the test procedure has evidence of work performed and/or completed data entry. Verifications may be done either during or after the operation, as long as the operations and/or data readings can be verified. (Ref: TI-MH 3278200 para 3.9.2)

Quality Engineer (QE):

- All test equipment, test setups, and collected data shall be subject to monitoring, review and validation by an authorized Quality Engineer (QE) per 326412. The signature or stamp of the cognizant QE shall indicate validation. (Ref TI-MH 3278200, Para 3.9.)

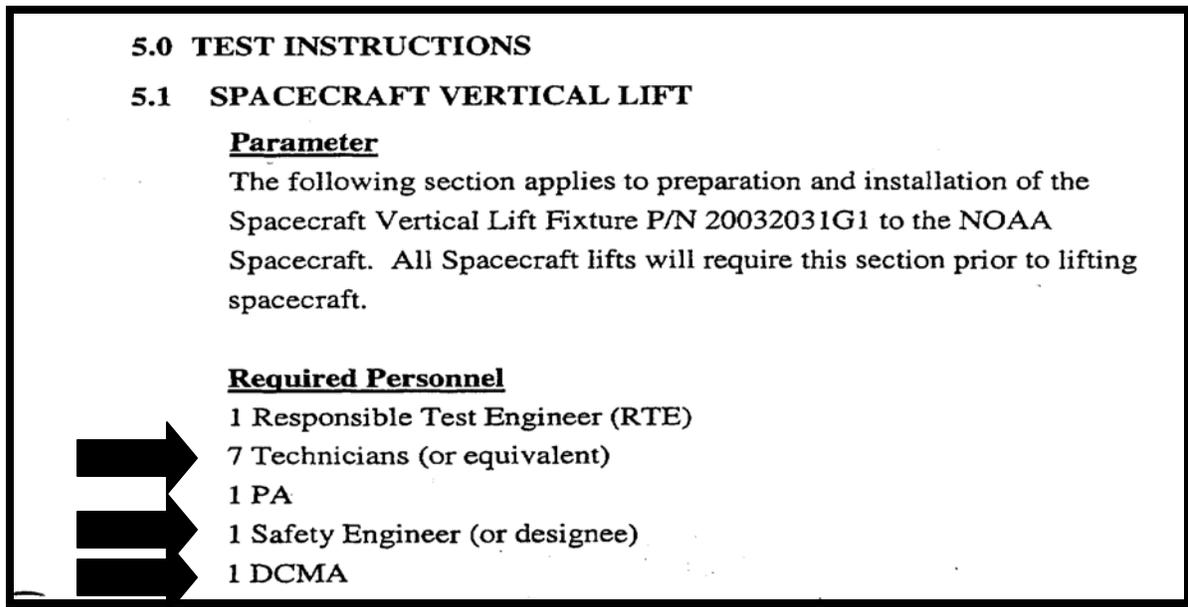
### 5.3.3 Staffing and Notification of Safety, PA/QA), and DCMA/QAR (Gov't Rep)

Several required members of the crew were not involved in the basic planning leading up to the Saturday morning activity, particularly Safety, Product Assurance (Quality Assurance), and the Government Representative (DMCA or QAR), as required by the procedure. Attempts were made to contact Quality Assurance and the QAR on Saturday morning as the operation was in the preparation stages. The PA (QA) inspector was the only one who actually participated.

The MIB observed an inadequate emphasis on safety and Quality Assurance within the TIROS program. Few resources are allocated to this function and few requirements for safety oversight exist. Further, little LM and GSFC programmatic supervision was provided for the safety representatives. A shrinking of the Quality Assurance activity was also observed as the program work diminished, with three inspectors now being shared between the TIROS and DMSP projects. (Findings L-10, G-3, and G-8)

#### **5.3.3.1 Safety**

The procedure for installation of the spacecraft on the Turnover Cart (TOC) specified “1 Safety Engineer (or designee)” as part of the Required Personnel list. (Figure 5-16: TI-MH-3278200 Staffing Requirement). Safety was not notified of the operation, and a note was entered in the margin of the procedure to that effect (Figure 5-17: Procedure Record Documented That Safety Not Notified). In fact, the primary Safety Engineer was on travel supporting a launch planned by the DMSP program. An alternate Safety Engineer was specified during the primary Engineer’s absence, but no attempt was made to contact either the primary or the alternate. It was clear from this, and from previous operations indicating that Safety was notified but did not attend, that Safety was not considered an essential element of spacecraft lifting operations. This lack of involvement was not questioned by supervision. (Findings L-3, L-9, L-10, and L-13)



**Figure 5-16: TI-MH-3278200 Staffing Requirement**

In practice, the role of Systems Safety appears to be to review procedures to ensure the appropriate safety precautions are included, and to produce and coordinate the launch area safety data package, commonly known as the Missile System Prelaunch Safety Package (MSPSP). It was not common practice for Systems Safety to attend and oversee critical operations unless there is something unique about it. (Finding L-10 and G-8)

In addition, the required number of technicians specified (7) was reduced but not noted. The reduced staff was considered acceptable because the lifting sling had been modified to eliminate the need for four (4) of the seven (7) technicians. The sole responsibility of the eliminated technicians was stated to be holding the lifting sling legs away from the spacecraft using four (4) tag lines, one at each corner. While the eliminated technicians specified roles are not significant in the lifting operation with the newly modified sling, the absence of four (4) additional pairs of eyes and ears cannot be completely overlooked.

**Figure 5-17: Procedure Record Documented That Safety Not Notified  
Proprietary Information**

### **5.3.3.2 Product Assurance (PA or QA)**

The Quality Assurance Inspector, variously referred to as Product Assurance (PA) or Quality Assurance (QA), was not present during the initial preparations and was called shortly after the preparations began on Saturday morning. He was on site and present in the building when called, but was on his way to support his regularly scheduled activity

on another program in another building. He consented to support the NOAA N-PRIME activity, and changed his plans accordingly. He entered the high bay 6:42am.

By the time he arrived, the preparations of the TOC and the spacecraft were basically complete, and the operation was ready to proceed. He had to make the decision of whether to delay the operation to verify the procedure steps he was supposed to witness, which were already completed by the technicians, or to stamp-off the procedures based on his trust and knowledge of the technician crew and the RTE. He stamped off the procedure without actually inspecting or witnessing the TOC preparation activities or configuration. This practice apparently was tolerated by management and supervision, as DCMA had written numerous Corrective Action Reports (CARs) addressing stamping violations. (Refer to Findings G-2 and G-9, and Section 9.2)

### **5.3.3.3 DCMA or QAR (Gov't Rep)**

The GSFC Quality Assurance Representative (QAR) was notified at home on Saturday morning after preparations were underway, but prior to the actual lift. An informal (email) agreement between the GSFC Systems Assurance Manager (SAM) and the DCMA had relieved the DCMA Representative from having to support weekend activities, and therefore the RTE called the QAR. The QAR gave his verbal OK to proceed with the lifting operation and indicated that he would be in as soon as he could. The assumptions behind this OK to proceed are unclear, but it is concluded by the MIB that the QAR understood the critical activity requiring his presence was the actual MHS instrument shimming, rather than the movement and lifting/rotation of the spacecraft. It is questionable whether he fully understood the function, scope, and practices of the DCMA representative in agreeing to substitute for the DCMA representative on weekends. The MIB concluded that he was unaware of the Mandatory Inspection Point (MIP) that required Government Representative presence for all movements of the spacecraft. He arrived on the scene at 8:25am, after the spacecraft had already fallen. (Finding G-2)

Since the operation was consistently characterized as routine and low risk, even though it involved moving the spacecraft, there is strong evidence of complacency involved in the permission to proceed. (Findings L-4 and L-9)

An additional factor that probably had an influence on the QAR's oversight and decision making was the fact that he was the retired LM Product Assurance Manager. In that role, he was very well acquainted with the personnel and processes, and may not have exercised a fully objective oversight of the LM activities. (Finding G-6) DCMA had written numerous Corrective Action Reports (CARs), but had failed to follow up for corrective action implementation. Included in the list of CARs were several instances of stamping, or buy-off, violations. This contributed to the lax process environment. A more complete discussion and analysis of the DCMA CARs is included in Section 9. (Finding G-4)

## 5.4 Turnover Cart

The following sections recount the sequence of events leading to the cart configuration on the day of the mishap.

### 5.4.1 Cart Use by NOAA N

The Turnover Cart (TOC) was in use by the NOAA N spacecraft from August 6 through August 26, after which the TOC was relocated from the NOAA High Bay to the Ante Room or common area between the TIROS NOAA and the DMSP High Bays. The same basic operation had been performed, except that the MHS Shimming was done during the MHS installation, rather than requiring the MHS removal, then reinstallation with shimming. The timeline and Hi-Bay area layout is shown in Figures 5-18: TIROS and DMSP Timeline, and 5-19: LMSSC Hi-Bay Area. It was after this use by NOAA N that the TOC reconfiguration by DMSP was initiated and interrupted, leading to the 24 bolts being missing.

### 5.4.2 Cart Reconfiguration by DMSP and Red Tag Procedures

The DMSP and TIROS programs have routinely shared Mechanical Ground Support Equipment (MGSE) throughout their histories because of the similarity of the spacecraft. However, each spacecraft and unique test configurations required the use of unique adapters between the spacecraft flight payload adapter and the TOC itself. The two programs are currently housed in the same building and share a common Ante Room (storage/staging area) between their respective high bays. It was common practice to utilize each other's MGSE when beneficial to the program. Communication between the I&T Managers of each program was informal and substandard. Communication issues surrounding the use of shared ground equipment had apparently existed between the DMSP and TIROS programs for some time, and had been the cause of conflict in the past. No common schedule existed with which to avoid equipment conflicts and overlaps. (Finding L-5)

**Figure 5-18: TIROS and DMSP Timeline**  
**Proprietary Information**

# B152 I&T Areas

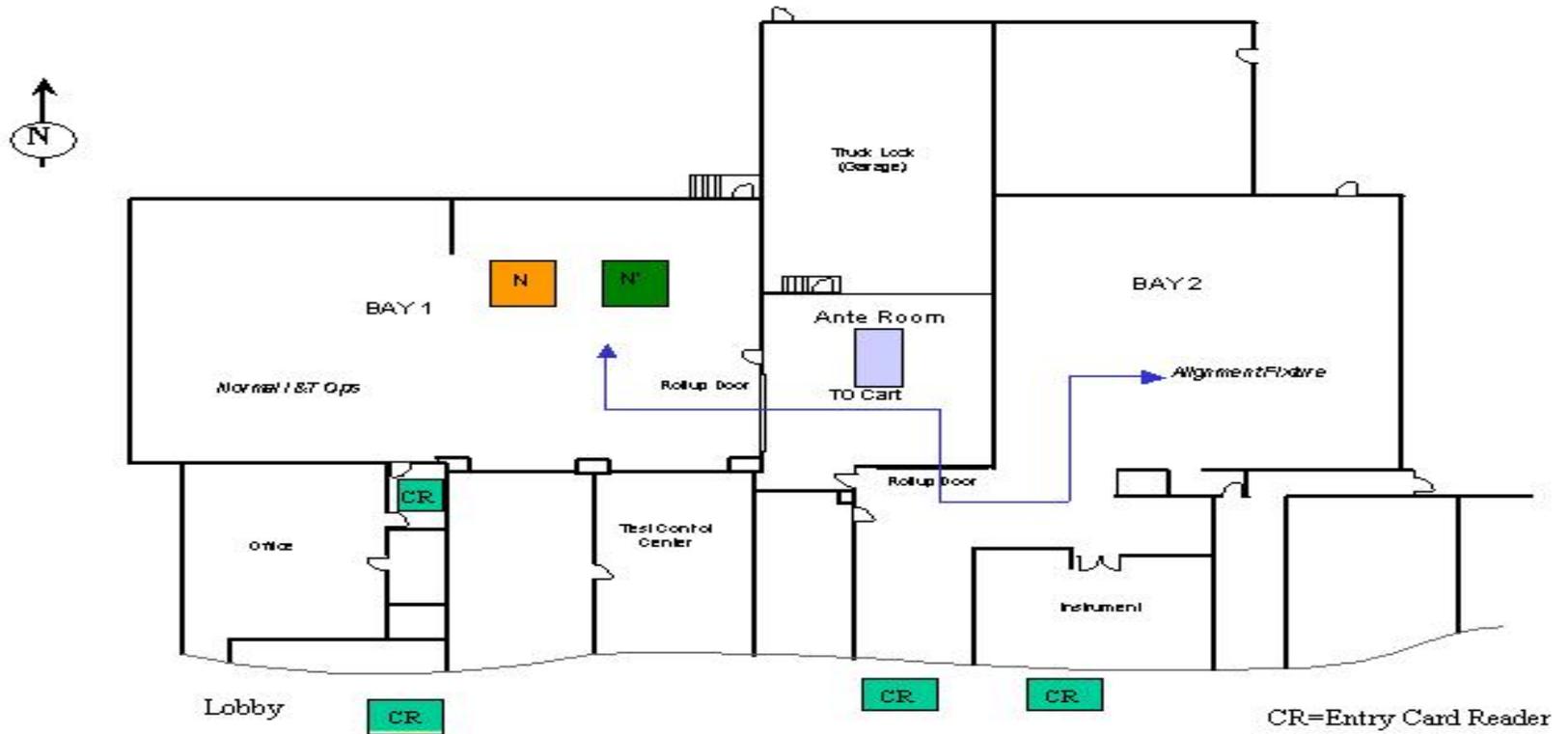


Figure 5-19: LMSSC Hi-Bay Area

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After completion of NOAA N activities using the TOC, the cart was returned to the common Ante Room. The DMSP Program decided to use this TOC for its activities because their own TOC was red-tagged with a problem. Activities to reconfigure the TOC for their own configuration began on August 27. The reconfiguration was interrupted part way through the process of the TIROS adapter ring removal, in order to install the DMSP adapter, when it was discovered the TIROS TOC was red tagged and it was determined that it would be easier for DMSP to clear the red tag on its own TOC. This change in plan left the TIROS adapter ring sitting on the TIROS TOC with its 24 attachment bolts removed. (These are the 24 bolts in question.) No red tag nor any other indication was added to the TIROS TOC to indicate the incomplete configuration; the TIROS TOC remained red-tagged due to a floor jack problem. (Figure 5-20: TOC showing Adapter Plate with 24 Missing Bolts; Figure 5-21: DMSP TOC Configuration with TIROS Adapter Plate; and Figure 5-22: TOC Diagram side view) None of this was communicated to the TIROS folks, nor was it required by the LM Command Media because the over-riding philosophy was that each user was required to verify or ensure the GSE configuration was appropriate for its own specific use each time it was used.

Finally, no real communication or documentation process existed for handling the red-tagging, repair and maintenance of ground support equipment. In this particular case, the repair of the cart did not return it to its full capacity—a restriction that was not communicated beyond the DMSP I&T manager (requester of repair) and the Technician Supervisor (repairer). The red tag process is so informal that the Red Tags that were utilized informally were discarded after their particular concerns were resolved, leaving no record of the Red Tag process. (Finding L-5)

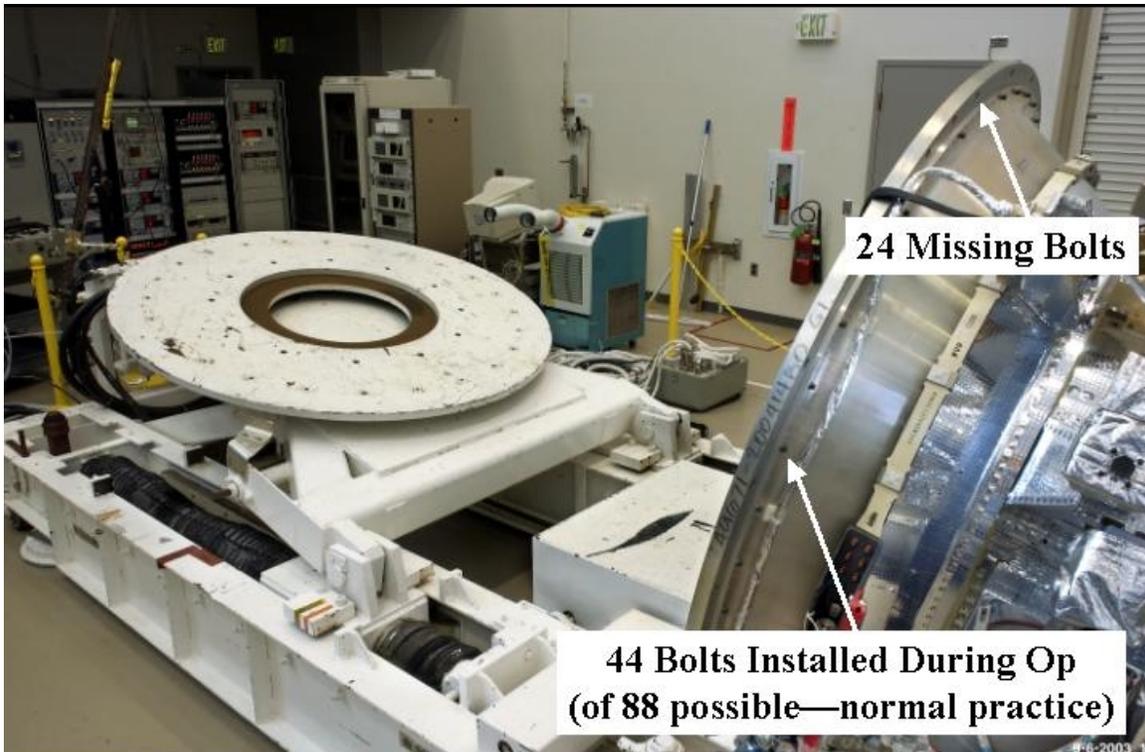
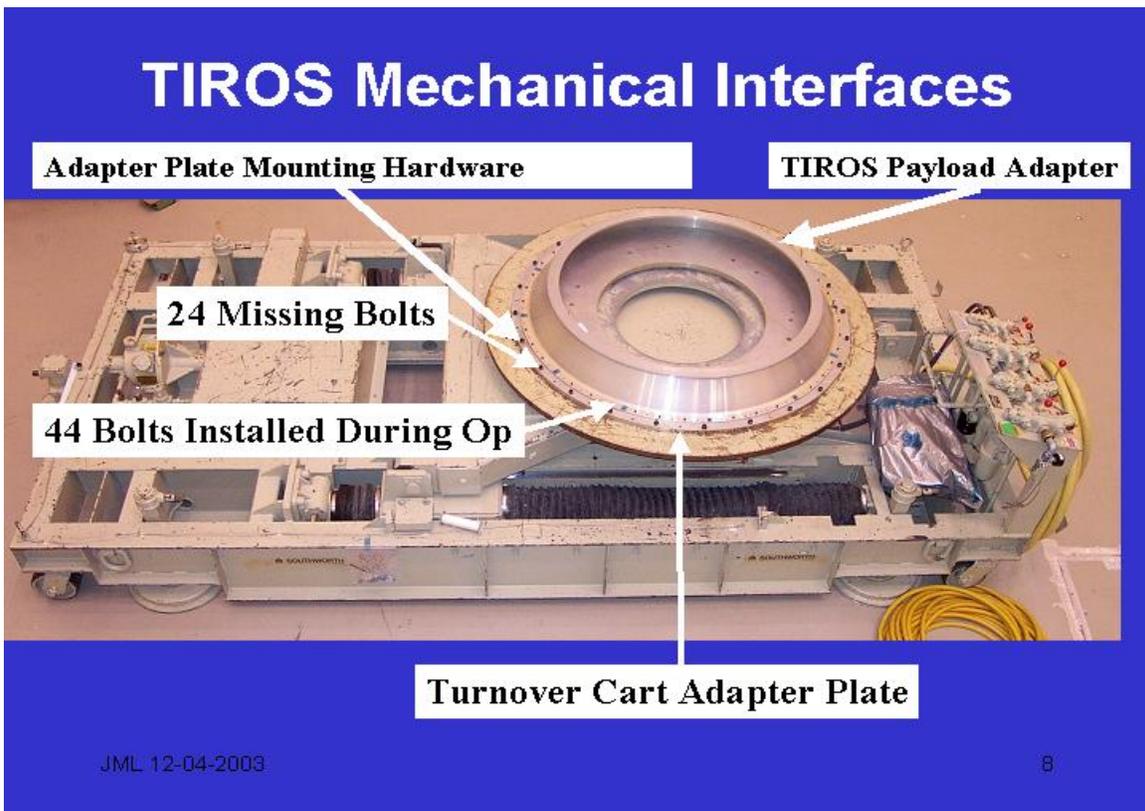


Figure 5-20: TOC Showing Adapter Plate with 24 Missing Bolts



**Figure 5-21: DMSP TOC Configuration (with TIROS Adapter Plate in Position)**

**Figure 5-22: Adapter, Adapter Plate, and Southworth TOC Interface Place  
Proprietary Information**

Several versions addressing where the missing bolts went after they were removed from the TOC were heard during interviews. Two examples heard were that: 1) the bolts went to the DMSP cart; and 2) that the bolts went into the common area storage cabinet. Since the LM system considers the GSE as uncontrolled until its configuration is verified by the using project for each use, the actual version of the bolt story is not important in establishing the cause of this mishap.

**5.4.3 Cart Rework by NOAA N-PRIME**

TIROS NOAA N-PRIME personnel worked off the red tag on the TIROS TOC on Thursday and Friday, September 4 and 5. The repair consisted of replacing the damaged jack. Because a jack of the same load rating was not available, a jack with a lower rating was utilized. Engineering analysis concluded the replacement jack was of sufficient capacity for static use of the cart, but analysis showed it was insufficient to permit movement of the TOC with the spacecraft attached. This limitation resulted in a slight change to the spacecraft lift and mating procedure. Instead of using the crane to maneuver the spacecraft over the cart and lower into position as specified, the spacecraft was raised and the TOC positioned under the suspended spacecraft. No redlines or other notations were made in the procedure to indicate this change. (Ref TI-MH 3278200 Section 5.6.4) This change is not deemed significant, but is an indicator of the lack of procedure discipline.

**5.5 Day of the Mishap**

The Saturday operation proceeded as planned, with the exception of the availability and late notification of PA and the NASA Quality Assurance Inspector (QAR--Customer Representative), and the lack of notification of Systems Safety. A detailed view of the Saturday timeline is presented in Figure 5-23: Saturday Detailed Timeline. The vertical axis is separated by specific procedure in order to group items from specific authorizing documents: the Program Directive (PD), the Log of Operations (LOO), and the two primary Technical Instruction procedures (TI-MHS3278200 and TO-MH-3278200). Several parallel preparation activities were completed on Friday, making the spacecraft ready to begin the operation early on Saturday morning. The apparent jumping up and down indicates the difficulty in following the correct sequence of steps.

The precise timeline for Saturday, the day of the incident, is somewhat speculative, but was reconstructed using both witness statements and by the supporting high bay door entry log. The

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pace of the activity seems quite fast for such critical and delicate lifting operations, but interviewees indicated that the operation went very smoothly and was not rushed.

### 5.5.1 Preparation 6:00 – 6:45am:

The work shift began at 6:00am on Saturday, September 6. The starting time was normal for the technicians, and is consistent with normal weekday start times. As was normal work practice, the technicians preferred to start early to leave time for personal activities later in the day.

Personnel began entering the High Bay at 6:07am, as confirmed by the entry badge reader, and continued to enter until approximately 6:13am (Figure 5-24: Door Entry Log). During that time, the Responsible Test Engineer (RTE), Technician Supervisor (Technician Equivalent), Integration and Test Manager (I&T Mgr), and one Technician logged in to the High Bay. The arrival times of other technicians are not known because ‘tailgating,’ or following another person through the opened door, is an accepted practice.

The Lockheed Martin (LM) Quality Assurance Inspector (PA) was notified by phone at approximately 6:30am, thereby confirming that his first entry into the High Bay was at 6:42am, as recorded by the badge reader. He was on-site to cover another program, but agreed to support the NOAA N-PRIME activity. It is also known that NASA QAR was notified at home at about the same 6:30am time frame, and that his first entry into the High Bay did not occur until 8:25am. LM safety was not notified of this operation at all, including on Saturday as required by the procedure (Note: Further discussion of this is noted in Section 5.2, Planning and Procedures, and 5.3, Crew Makeup).

### 5.5.2 TOC Preparation and Assurance 6:07 – 6:45am:

The activities required to “Assure Turnover Cart Configuration” are specified in the procedure TI-MH 3278200, step 5.6.1. The first step in that section refers to the “Spacecraft Turnover Assembly Section of this procedure”, which is Section 5.5. (Figure 5-25: Excerpt from Section 5.6 Referring to Section 5.5) During this activity, the TOC was moved from the common staging area (Ante Room) into the NOAA High Bay and prepared to support the NOAA N-PRIME activity. These activities were completed prior to 6:45am. The cart was prepared by the lead technician (PQC), and signed off in the procedure by the PQC, RTE, and PA. The following discussion reflects the steps in the procedure required to accomplish this preparation. Note that Step 5.6.1 refers to another section of the procedure, but does not provide the paragraph number of the section.

The preparation of the TOC was intended to be performed in accordance with TI-MH- 3278200, Section 5.5. The note at the beginning of this section states:

*“NOTE: During this section, the following disciplines will be responsible for the verifications identified during buy-off in Table 5.5-1:*

**PQC – All steps followed and performed**

RTE – All steps performed and any torque witnessing

PA – All steps successfully completed”

The rest of this section is Export Controlled

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**Figure 5-23: Saturday Detailed Timeline**

## TIROS (NOAA N-Prime) PERSONNEL DOOR ENTRY LOG

ID	Task Name	Start	Sat Sep 6, 6 AM												Sat Sep 6, 7 AM												Sat Sep 6, 8 AM											
			45	50	55	0	5	10	15	20	25	30	35	40	45	50	55	0	5	10	15	20	25	30	35	40	45	50	55	0	5	10	15	20	25	30	35	40
1																																						
2	<b>RTE</b>	Sat 9/6/03 5:54 AM																																				
3	<b>DbI Doors</b>	Sat 9/6/03 5:54 AM	◆ DbI Doors																																			
4	<b>HiBay</b>	Sat 9/6/03 6:08 AM	◆ HiBay																																			
5	<b>HiBay</b>	Sat 9/6/03 6:08 AM	◆ HiBay																																			
6	<b>HiBay</b>	Sat 9/6/03 7:41 AM	◆ HiBay																																			
7	<b>HiBay</b>	Sat 9/6/03 7:49 AM	◆ HiBay																																			
8																																						
9	<b>Tech Supv</b>	Sat 9/6/03 6:07 AM																																				
10	<b>Bldg</b>	Sat 9/6/03 6:07 AM	◆ Bldg																																			
11	<b>HiBay</b>	Sat 9/6/03 6:10 AM	◆ HiBay																																			
12	<b>HiBay</b>	Sat 9/6/03 6:20 AM	◆ HiBay																																			
13	<b>HiBay</b>	Sat 9/6/03 7:29 AM	◆ HiBay																																			
14	<b>HiBay</b>	Sat 9/6/03 7:32 AM	◆ HiBay																																			
15																																						
16	<b>I&amp;T Mgr</b>	Sat 9/6/03 6:12 AM																																				
17	<b>HiBay</b>	Sat 9/6/03 6:12 AM	◆ HiBay																																			
18	<b>HiBay</b>	Sat 9/6/03 6:45 AM	◆ HiBay																																			
19	<b>DbI Doors</b>	Sat 9/6/03 7:45 AM	◆ DbI Doors																																			
20																																						
21	<b>Tech-DMSP</b>	Sat 9/6/03 6:07 AM																																				
22	<b>DbI Doors</b>	Sat 9/6/03 6:07 AM	◆ DbI Doors																																			
23	<b>HiBay</b>	Sat 9/6/03 6:13 AM	◆ HiBay																																			
24	<b>DbI Doors</b>	Sat 9/6/03 7:42 AM	◆ DbI Doors																																			
25																																						
26	<b>LM QA</b>	Sat 9/6/03 6:09 AM																																				
27	<b>DbI Doors</b>	Sat 9/6/03 6:09 AM	◆ DbI Doors																																			
28	<b>DbI Doors</b>	Sat 9/6/03 6:40 AM	◆ DbI Doors																																			
29	<b>HiBay</b>	Sat 9/6/03 6:42 AM	◆ HiBay																																			
30	<b>HiBay</b>	Sat 9/6/03 7:46 AM	◆ HiBay																																			
31	<b>ASSURE TURNOVER CART</b>	Sat 9/6/03 6:17 AM	<div style="background-color: #ccccff; width: 100%; height: 15px; margin-bottom: 5px;"></div> TURNOVER CART CONFIG 'ASSURANCE' DURING THIS PERIOD																																			
32																																						
33	<b>NASA QA</b>	Sat 9/6/03 8:16 AM																																				
34	<b>DbI Doors</b>	Sat 9/6/03 8:16 AM	◆ DbI Doors																																			
35	<b>HiBay</b>	Sat 9/6/03 8:25 AM	◆ HiBay																																			

Entry Log Timeline.mpp Page 1 Wed 1/7/04 9:04 PM

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Figure 5-24: Door Entry Log

**Figure 5-25: Excerpt from Section 5.6 Referring to Section 5.5)  
Export Controlled**

**Figure 5-26: Excerpt from Section 5.5 Assuring TOC Configuration  
Export Controlled**

5.5.3 Hoist and Secure S/C 6:45 – 7:06 am:

The most probable start time of the actual hoisting activity was 6:45am. This time is established because PA arrived in time to stamp off the procedure asserting the acceptable configuration of the TOC (6:42am), PA was there for the beginning of the lift, and the I&T Manager reentered the High Bay at 6:45am, in time for the lift to begin (per his request to be present for the lift). This established the team as constituted for the lift activity. A time of 7:06 is ascribed as the end of the hoisting activity based on backing up from the next two operations: Rotate Vertically, and Rotate to Horizontal.

It would be during this time that the RTE would have conducted the required Safety Briefing. The Error Prevention Program adopted by LMSSC utilized the AESOP acronym as a memory tool addressing the major elements that help to focus the participants. Each crew member carries a card reminding them of the elements of AESOP, which are:

A	Assignment: Clear? Complete? Risks?
E	Equipment: What? Availability? Working?
S	Situation: Overall Assessment (Go, Ragged Edge, Stop)
O	Obstacles: Potential Problems? Look ahead!
P	Personnel: Who? Experience? Risks? Review I'M SAFE: Illness * Fatigue * Eating

The AESOP process is intended to be implemented by stepping through each letter of the acronym to ensure all aspects of the ensuing activity are understood by all members of the activity.

There are conflicting reports on the fidelity and extent of the briefing. Some reports indicate a briefing was held; others do not remember a briefing. This briefing is intended to cover individual roles and responsibilities, safety equipment, sequence of activities, etc. (See Section 5.3.2) The conclusion is that if a briefing was held, it probably did not include the entire crew, and was most probably just a short discussion among a select few individuals. Also, it is most

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probable that the AESOP process was not followed since so many members of the team do not remember participating in a briefing. The lack of a briefing sufficient enough for most of the team members to remember it is deemed inadequate supervision. (Finding L-7)

Personal interviews and answers to MIB questions during presentations to the Board indicated a strong reluctance to speak up and hold up an operation unless an individual was absolutely sure something was wrong. Merely having an uncomfortable feeling about the pending operation was not an acceptable reason for speaking up. This led to the ineffectiveness of the Error Prevention Program.

During the operation, the Technician Supervisor commented that there were empty bolt holes, a conversation that was overheard by several of the technicians. The team and the RTE in particular dismissed the comment and did not pursue the issue further.

Evidence that the operation proceeded at an accelerated pace was expressed by the majority of the operations team, although the precise reason for the acceleration was varied. It is the MIB's belief that the RTE was anticipating his departure and may have hurried through the procedures. The fact that all of the preparations were completed, the entire lifting/mating operation was completed, and the TOC vertical and horizontal rotation activities were begun in the space of one hour was recognized as highly unusual, yet raised no flags of caution.

### 5.5.4 Rotate Vertically 7:06 – 7:16 am:

A time of 7:06 is ascribed as the start of the vertical rotation to orient the spacecraft instrument package to an orientation that will put it on the upward side of the spacecraft when the spacecraft is rotated to the horizontal position. The TOC is known to take 5-10 minutes to rotate 180 degrees. While the exact magnitude of the rotation is not known, 10 minutes is a reasonable period to allocate to the activity, including preparation. The spacecraft did not slip or otherwise 'wobble' because of the weight of the spacecraft and the large contact surface area creating significant friction between the unbolted plates. This activity can be likened to slowly rotating a carousel or "Lazy Susan" with an item or items sitting on it with no means of securing other than simple friction. (Note: This activity is not described nor specified in the procedure, but was determined to be standard practice by the I&T Team. Normally, it was done to put the instrument package in the minimum risk position for horizontal rotation, but in this case, it was necessary for the MHS Shimming Operation.)

The team was using Appendix C of the TI-MH 3278200 procedure for operation of the TOC. That section provides a general description of how to operate the TOC, rather than a step-by-step procedure. The section requires: 1 RTE, 4 Technicians, 1 Quality Inspector, and 1 Customer Representative. The large number of technicians is required because the TOC is normally maneuvered with a technician located at each corner. For this NOAA N-PRIME activity, the TOC had been maneuvered under the suspended spacecraft, and would not be maneuvered with the spacecraft attached because of the substandard floor jack repair. This is a second area in which the number of personnel prescribed in the procedure was not adhered to, but is not seen as a contributor to the incident.

5.5.5 Rotate to Horizontal 7:16 – 7:28 am:

A time of 7:16 is ascribed as the start of horizontal rotation. This time was determined by backing up from the actual time of the incident, along with calculating the time it took the TOC to reach 13 degrees of rotation. The cart is described as taking approximately 45 to 60 minutes to rotate from vertical to horizontal. Based on the 13 degree angle at the time of the incident, the rotation time ascribed is 13/90ths of 45 minutes, or approximately 7-8 minutes for actual time of rotation, plus a short time for the TOC operator to power the cart and begin the rotation. This establishes the probable time of rotation. It was not determined whether the angular rotation rate is linear during the entire 90 degrees, but this estimated duration is only relevant for helping to distribute the activities between attaching the lift fixture and the incident appropriately throughout the period to aid in gaining a sense of the pace of the activity. No other documentation exists to aid in timing determinations.

In the 21 minutes between 6:45 and 7:06, the following steps and sections of the procedure were performed (Ref TI-MH 3278200, Section 5.6) (See also Table 5-1: Operations Event Timeline, and Figure 5-23: Saturday Detailed Timeline). (Note: The steps below are abbreviated descriptions because the individual steps do not have titles.)

5.6.2 Attach S/C vertical lift fixture per 5.1

5.6.3 Position personnel for Lift

5.6.4 Lift S/C over TOC

5.6.5 Offload crane to 1000 lbs

5.6.6 Install and torque 44 places\*

5.6.7 Offload all crane load

5.6.8 Remove lift fixture

5.6.9 Torque check 44 fasteners\*

5.6.10 Continue with authorizing document

\*Activities in close proximity to missing bolt holes

In addition to the steps specified in the procedure above, the crew is known to have performed two additional steps, one of which is significant. They wiped the mating surfaces between the spacecraft Payload Adapter and the TOC Adapter Ring with isopropyl alcohol (a standard but undocumented procedure). This is significant because this action wiped directly over the missing-bolt holes. The heads of these missing bolts normally protrude above the adapter plate surface. The fact that the technicians wiped this surface without encountering the normal interference of the bolt heads is significant. A skill-based error was made by the crew: the technicians were narrowly focused on their individual tasks and did not notice or consider the state of the hardware or the operation outside of those tasks. This type of error is common in highly structured, repetitive tasks and each technician, when interviewed, commented on the large number of times these procedures had been successfully attempted in the past. In addition, each technician commented that the RTE had full authority and responsibility for the operation and that their role was to follow the RTE's instructions; a culture proved to promote the type of channelized attention observed. While it is absolutely clear that it is the RTEs function to direct the tasks for each crew member, each crew member is also qualified for specific functions. Qualified technicians are expected to exercise their expertise in the performance of their tasks. (Finding L-2) (**MISSED OPPORTUNITY #3**)

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The second added step was the rotation of the S/C about its vertical axis to put the instrument package in the preferred orientation with the instruments on the 'up' side of the spacecraft when in the horizontal position. This missing step is significant only as it points to the fidelity of the procedures. The outcome would have been the same with or without the spacecraft rotation except for the possible extent of the resultant damage.

No details are available to further document the actual times of each of the above steps in the procedure except witness statements that the lift occurred 'about 7am'. This is consistent with the activities that occurred, and the actual time of the incident.

The Board feels very strongly that in order for a small crew of two engineers and two technicians to accomplish the sequence of activities necessary to hoist the spacecraft and prepare for rotation to horizontal, including torquing and re-torquing the 44 fasteners holding the spacecraft to the adapter ring, the pace of the activity was very fast. In fact, members of the crew recognized that, "This was the smoothest this operation has ever gone." (**MISSED OPPORTUNITY #4**)

The time of 7:28am is established as the time of the incident because the Technician Supervisor stated that 'he immediately left the high bay to summon the I&T Manager.' He actually re-entered the High Bay at 7:29am.

### 5.6 Summary of Missed Opportunities

Missed Opportunities have been identified above during the course of the analysis. Table 5-3: Missed Opportunities, summarizes those opportunities, grouping them to provide a sense of the pace and tenor of the operation.

No.	MISSED OPPORTUNITY	SECTION No.
1	<p><b>Conversation Between RTE and Technician Supervisor:</b> At least one of the crew members was uncertain and nervous about seeing ‘holes with threads’, but did not have sufficient experience with the TIROS TOC-to-spacecraft configuration to recognize the reality of the situation.</p>	5.3
2	<p><b>TOC Verification:</b> The verification of the TOC was not performed as required by procedure. PA was not present to witness as required.</p>	5.5.2
3	<p><b>Mating Surface Wipe-down:</b> Experienced Technicians performing the mating surface wipe down with isopropyl alcohol failed to realize that they were wiping over holes where bolt heads normally protruded and would make the wipe down more difficult.</p>	5.5.5
4	<p><b>Ease of Spacecraft Mate:</b> Most of the crew members were aware of how smoothly the spacecraft mating operations went, but none recognized that it was due to the lack of impediment normally caused by the presence of the 24 adapter mating bolts.</p>	5.5.5

**Table 5-3: Missed Opportunities**

### 5.8 Summary

Several elements contributed to the NOAA N-PRIME incident, the most significant of which were the lack of proper TOC verification, including the lack of proper PA witness, the change in schedule and its effect on the crew makeup, the failure of the crew to recognize missing bolts while performing the interface surface wipe down, the failure to notify in a timely fashion or at

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all the Safety, PA, and Government representatives, and the improper use of procedure redlines leading to a difficult-to-follow sequence of events. The interplay of the several elements allowed a situation to exist where the extensively experienced crew was not focusing on the activity at hand. There were missed opportunities that could have averted this mishap. The missed opportunities are summarized in Section 5.6.

Table 5-4, Findings Summary (LMSSC), and Table 5-5, Findings Summary (government) provide a cross-reference between the Findings discussed in Section 7 and the descriptions in Section 5.

<b>Table 5-4: Findings Summary (LMSSC)</b>		
<b>NO.</b>	<b>PARA.</b>	<b>FINDING</b>
<b><u>UNSAFE ACTS</u></b>		
L-1	5.5.2	1) RTE committed a “decision error” by not following procedures.
L-2	5.3.1 5.3.2	2) Technicians committed “skill based error” by not noticing the missing bolts while wiping down interface plate and bolting down the spacecraft.
L-3	5.3.3.1 5.5.2  5.3.3.1	3) A) PQC and PA inspector committed “routine violations” by signing-off on operations without witnessing and verifying TOC configuration.  B) The safety representative was not present as called for in the procedure.
<b><u>PRECONDITIONS FOR UNSAFE ACTS</u></b>		
L-4	5.3.1 5.3.3.3	4) Adverse mental states in the forms of “channelized attention”, “complacency”, and “get-home-itis” resulted in an accelerated pace of operations and procedure execution.
L-5	5.3 5.4.2	5) “Substandard crew resources” included poor hand-off between the DMSP and TIROS Projects regarding the TOC, late identification of personnel to work Saturday, and poor red-tagging process for GSE.

<b>Table 5-4: Findings Summary (LMSSC)</b>		
<b><u>UNSAFE SUPERVISION FACTORS</u></b>		
L-6	5.2 5.3	6) “Planned an inappropriate operation”- The team was formed late in a hurried fashion with an atypical mix of personnel.
L-7	5.5.3	7) “Inadequate supervision” was manifested in the lack of clear definition and enforcement of roles and responsibilities among the team individuals, consequently individuals failed to fulfill their expected roles and responsibilities.
L-8	5.5.2	8) “Failure to correct known problems” was a supervisory failure to correct similar known problems. PA supervisors routinely allowed PA inspector sign-off after the fact. I&T supervisors routinely allowed poor test documentation.
L-9	5.3.3.1 5.3.3.3	9) “Supervisory Violation” was committed by repeatedly waiving required presence of quality assurance and safety and bypassing Government Mandatory Inspection Points.
<b>NO.</b>	<b>PARA.</b>	<b>FINDING</b>
<b><u>ORGANIZATIONAL INFLUENCES</u></b>		
L-10	5.3.3.1	10) In “resource management”, MIB observed inadequate emphasis on safety, and inadequate quality assurance support to provide effective coverage.
L-11	5.2 5.3	11) The “Organization climate” in the I&T domain with an operational program has engendered an unhealthy environment that led to complacent and overconfident attitudes toward routine operations.
L-12	5.2	12) Lack of effective “Organizational Processes” in the form of guideline and safeguards to regulate the I&T environment.
L-13	5.3.3.1	13) Ineffective System Safety Program.

**Table 5-4: Findings Summary (LMSSC)**

<b>Table 5-5: Findings Summary (government)</b>		
<b>NO.</b>	<b>PARA.</b>	<b>FINDING</b>
<b><u>UNSAFE OVERSIGHT FACTORS</u></b>		
G-1	5.2.4	1) The government quality assurance and safety provided “inadequate oversight”. Oversight function became “issue driven”. Procedures rarely reviewed; non-conformances not trended; rarely make impromptu inspections.
G-2	5.3.3.3	2) In substituting for the DCMA, the QAR failed to enforce a Government Inspection Point by failing to enforce his presence at the operation.
G-3	5.3.3.1	3) Government has very limited safety oversight.
G-4	5.3.3.3 Sect. 8	4) Government “failed to correct known problems” such as PA signoff after the fact and poor test documentation.
<b><u>ORGANIZATIONAL INFLUENCES</u></b>		
G-5	5.2	5) Deficient “resource management” include: rapid trade-offs between the schedules, staffing and milestones for the two remaining satellites exacerbated the already fast operational tempo of the LMSSC I&T team, lack of resources in the safety area.
G-6	5.3.3.3	6) Unhealthy “organizational climate” factors include: using retired LMSSC employees as government representatives, lax and casual oversight toward an I&T environment with routine operations.
G-7	5.3.3.3 Sect. 8.2 Table 8-4	7) Government lacks “organizational processes” to effectively monitor, verify, and audit the performance and effectiveness of the I&T processes and activities.
G-8	5.3.3.1	8) The government safety program placed an overemphasis on launch site safety and inadequate in-plant safety.
G-9	5.3.3.2 Sect. 8.2 Table 8-4	9) Deficient DCMA CAR assessment and reporting processes.

**Table 5-5: Findings Summary (government)**

## SECTION 6

### METHOD OF INVESTIGATION

Three days after the mishap, on September 9, 2003, Dr. Ghassem Asrar, NASA Associate Administrator for Earth Science established the NOAA N-PRIME Mishap Investigation Board (MIB) in the public interest to gather information, conduct necessary analyses, and determine the facts of the mishap. (Appendix B) The board was chartered to determine the causes(s) of the mishap and to recommend preventive measures and actions to preclude recurrence of similar mishaps. In addition, the board would also investigate or determine the existence of potential systematic problems/practices with system reliability and quality assurance activities at the facility.

To identify the causes at work in the NOAA N-PRIME Mishap, the MIB collected evidence from the following sources:

- Witness interviews. All witnesses present at the mishap were interviewed along with key supervisory personnel and those connected with the events in question. Prior to being interviewed, each witness informed that this is a safety investigation to determine the cause(s) of the mishap and not legal liability, and that NASA will make every effort to keep testimony confidential. Alternatively read or informed of the following:  
"The purpose of this safety investigation is to determine the root cause(s) of the mishap that occurred on September 6, 2003, and to develop recommendations toward the prevention of similar mishaps in the future. It is not our purpose to place blame or to determine legal liability. Your testimony is entirely voluntary, but we hope that you will assist the board to the maximum extent of your knowledge in this matter. Your testimony will be documented and retained as part of the mishap investigation report background files but will not be released as part of the investigation board report. NASA will make every effort to keep your testimony confidential and privileged to the greatest extent permitted by law. However, the ultimate decision as to whether your testimony may be released may reside with a court or administrative body outside of NASA."  
Specific witness statements are not included in this text, as they are considered privileged and confidential.
- Test Procedures and Handling Instructions: The MIB reviewed all procedures that were used on NOAA N-PRIME at the time of the mishap (i.e., TI-MH-3278200 and TI-MHS-3278200), as well as related procedures called out by those documents both before and after the step at which the mishap occurred. These reviews included the Program Directives, Log of Operations, and similar documents. The review was not limited to NOAA N-PRIME, but also included a review of pertinent NOAA N procedures (also undergoing testing in the same integration and test area within the LMSSC-Sunnyvale facility) to identify whether similar actions had taken place in its processing.
- Non-Conformance Reports: The MIB reviewed all reports that could indicate a possible systemic problem.

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- Corrective Action Requests: The MIB reviewed DCMA Corrective Action Requests (CARs) from April 2001 to September 2003 to identify systematic problems with the LMSSC quality system at Sunnyvale facility.
- POES Management Plans: The MIB reviewed the Quality Assurance Plan, Safety Plan, and Configuration Management Plan.
- Other sources examined. Other sources reviewed included project schedules, contract requirements, LMC Command Media (i.e., corporate-level policies), experience of the Board members in working these types of programs, etc.

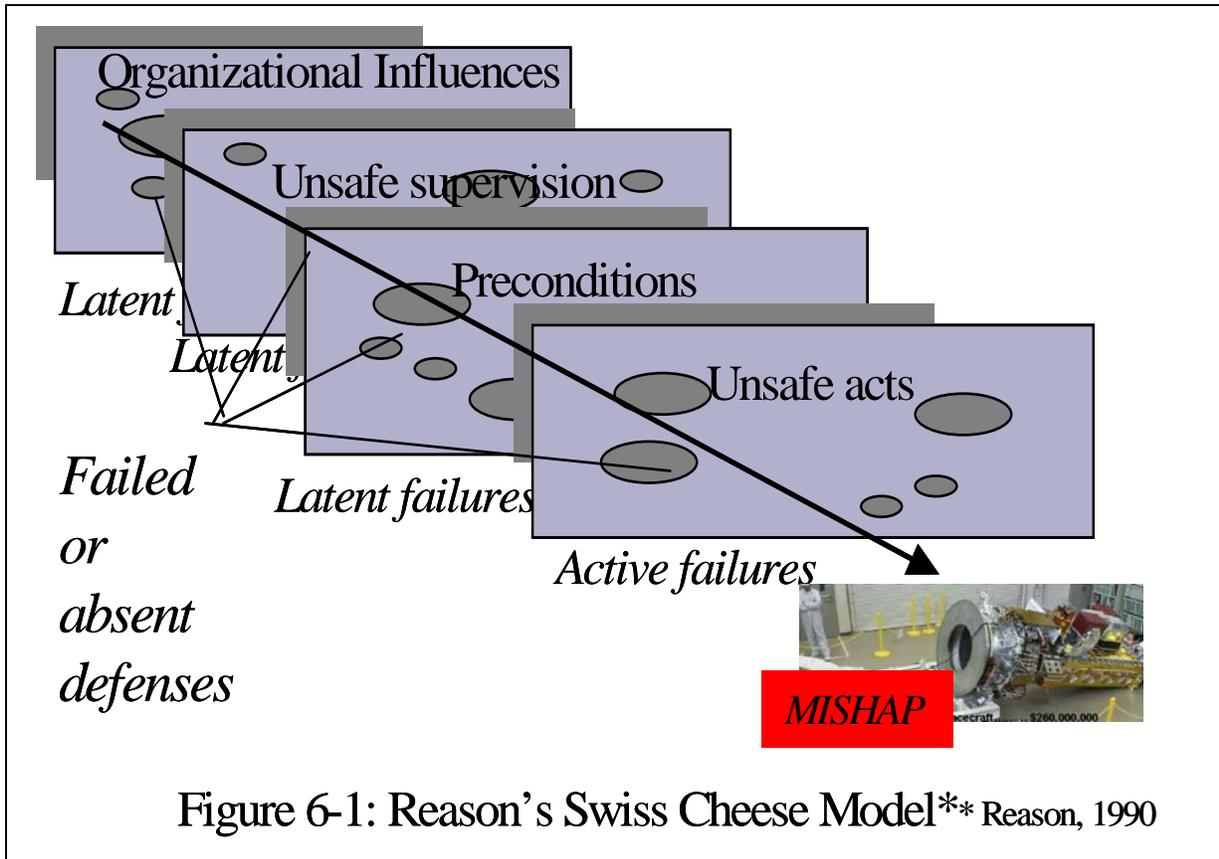
Two approaches were taken to determine the causes of the mishap. The first was an extensive analysis of the sequence of events prior to and on the day of the mishap; the planned operational scenario vs. the actual execution; and the planning activities, including scheduling, crew assembly and test documentation preparation. Missed opportunities that could have averted this mishap were also examined. This analysis is presented in Section 5.

The MIB also utilized the Human Factors Analysis and Classification System (HFACS) (2000) to examine the potential causes of the mishap. HFACS provides a comprehensive framework for identifying and analyzing human error. Further, it provides a method to categorize the findings or deficiencies and to formulate intervention strategies. HFACS is built upon James Reason's (1990) concept of latent and active failures or the so-called "Swiss Cheese" model. As shown in Figure 6-1, this model describes four levels of failure, each more removed from the actual accident than the last and yet each still influential due to its effect on the preceding level.

- The first level, or that most proximate to the accident, contains the "*Unsafe Acts*" of the operators. These acts are the active failures that lead directly to the occurrence.
- The second level of the model addresses the conditions and practices of the operators allowing the unsafe acts to occur, or "*Preconditions for Unsafe Acts*."
- Such preconditions can often be traced back to the supervisory level of the organization, which leads to the third level called "*Unsafe Supervision*."
- The final level of the Reason model deals with "*Organizational Influences*," which captures the organization's potentially adverse influence on the performance of the supervisors, operators, etc.

These last three levels describe latent failures, or those problems that may exist undetected or unchanged for some time before being manifested in an accident scenario. Within the four levels defined by Reason, HFACS creates greater resolution and granularity to the accident cause categories. While some categories are specific to aviation and pilot errors, most can be generalized to a broader class of accidents.

Using the evidence cited above, the MIB evaluated each sublevel of the HFACS approach and drew findings based upon the preponderance of evidence as to the presence of that cause. Levels 3 and 4 of the model were evaluated for both organizations involved in the mishap, LMSSC and the Government. A more detailed description of the HFACS model is also provided below.



## DESCRIPTION OF HFACS

For completeness of presentation, this section summarizes the HFACS methodology. A more detailed description of HFACS can be found in “The Human Factors Analysis and Classification System-HFACS” by Scott A. Shappell, February 2000, US Department of Transportation, DOT/FAA/AM-00/7.

### **Human Factors Analysis and Classification System (HFACS) Methodology**

The Human Factors Analysis and Classification System (HFACS) provide a comprehensive framework for identifying and analyzing human error. Its use was first tested in aviation accidents, in which an estimated 70-80% is attributable to human error. Over 300 Naval aviation accidents and numerous others from other military and civil aviation have been assessed using the current instantiation of this system.

The HFACS framework is built upon James Reason’s (1990) concept of latent and active failures or the so-called “Swiss Cheese” model. What convinced the MIB to use this model to analyze the mishap was its ability to address both active and latent failures within the causal sequence of events. As shown in Figure 6-1, this model describes four levels of failure, each more removed from the actual accident than the last and yet each still influential due to its effect on the preceding level. The first level, or that most proximate to the accident, contains the “Unsafe Acts” of the operators. These acts are the active failures that lead directly to the occurrence. The next three levels describe latent failures, or those problems that may exist undetected or unchanged for some time before being manifested in an accident scenario. Accordingly, the second level of the model addresses the conditions and practices of the operators allowing the unsafe acts to occur, or “Preconditions for Unsafe Acts.” Such preconditions can often be traced back to the supervisory level of the organization, which leads to the third level called “Unsafe Supervision.” And finally, the organization as a whole may adversely influence the performance of the supervisors, operators, etc. and hence, the final level of the Reason model deals with “Organizational Influences.”

Within these levels defined by Reason, HFACS creates greater resolution and granularity to the accident cause categories. While some categories are specific to aviation and pilot errors, most can be generalized to a broader class of accidents. These categories are described below.

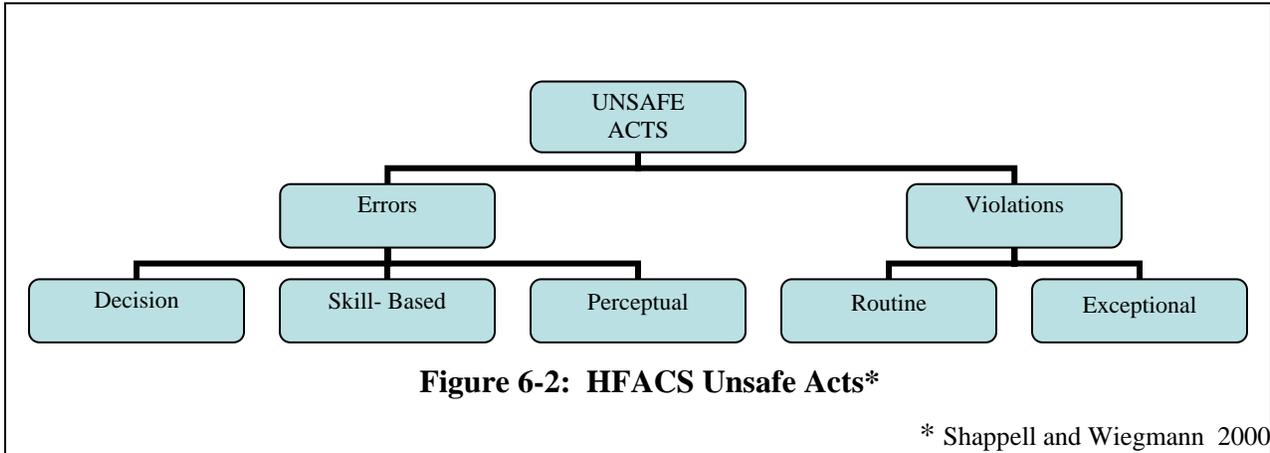
### **Unsafe Acts**

HFACS divides the Unsafe Acts level into two categories as shown in Figure 6-2: errors, which represent the actions or activities of the individuals who directly perpetrate the accident; and violations, which describe disobeying rules and/or standards of conduct or operation by these same individuals.

The error category is further refined as shown in Figure 6-2, by distinguishing among decision, skill-based and perceptual errors. A decision error refers to planned and executed behavior that proves to be inadequate or inappropriate to the situation at hand, due to poor choosing or insufficient information. A skill-based error, on the other hand, describes planned behavior that

is poorly executed. Finally, perceptual errors refer to misjudgments concerning sensory input, because of degraded or unusual information. Within each of these error categories, HFACS provides examples of specific accident causes. These are shown in Figure 6-3.

The violation category can be divided into two subcategories: routine, which are those violations that are habitual, normal, and often tolerated by authority; and exceptional, which are violations that are atypical or aberrations. Specific examples of violations are also shown in Figure 6-3.



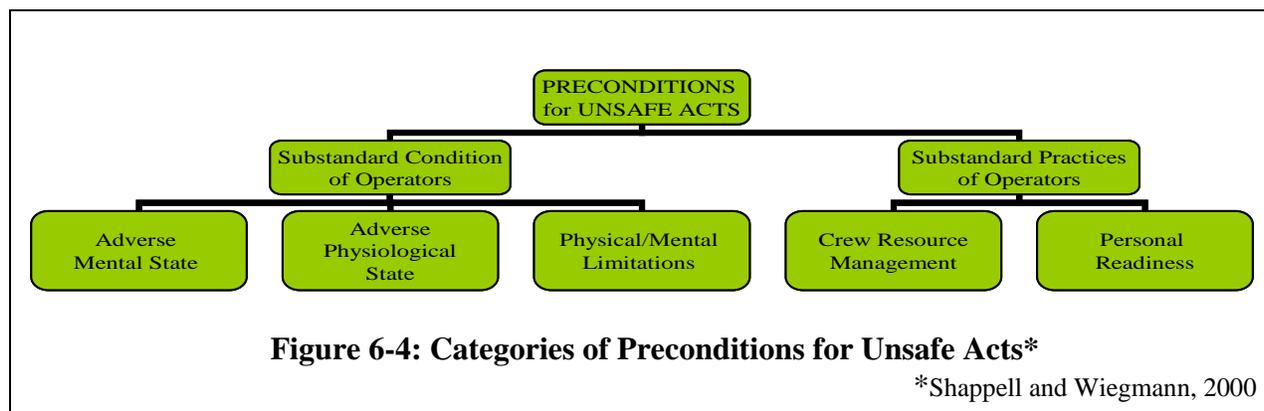
<u><b>ERRORS</b></u>	<u><b>VIOLATIONS</b></u>
<p><b>Skill-based errors</b></p> <ul style="list-style-type: none"> <li>• Breakdown in visual scan</li> <li>• Failed to prioritize attention</li> <li>• Inadvertent use of flight controls</li> <li>• Omitted step in procedure</li> <li>• Omitted checklist item</li> <li>• Poor technique</li> <li>• Over-controlled the aircraft</li> </ul> <p><b>Decision Errors</b></p> <ul style="list-style-type: none"> <li>• Improper procedure</li> <li>• Misdiagnosed emergency</li> <li>• Wrong response to emergency</li> <li>• Exceeded ability</li> <li>• Inappropriate maneuver</li> <li>• Poor decision</li> </ul> <p><b>Perceptual Errors (due to)</b></p> <ul style="list-style-type: none"> <li>• Misjudged distance /altitude/airspeed</li> <li>• Spatial disorientation</li> <li>• Visual illusion</li> </ul>	<ul style="list-style-type: none"> <li>• Failed to adhere to brief</li> <li>• Failed to use the radar altimeter</li> <li>• Flew an unauthorized approach</li> <li>• Flew an overaggressive maneuver</li> <li>• Failed to properly prepare for the flight</li> <li>• Briefed unauthorized flight</li> <li>• Non current/qualified for the mission</li> <li>• Intentionally exceeded the limits of the aircraft</li> <li>• Continued low-altitude flight in VMC</li> <li>• Unauthorized low-altitude canyon running</li> </ul>

**Figure 6-3: Examples of Unsafe Acts\***

\* Shappell and Wiegmann, 2000

**Preconditions for Unsafe Acts**

In the “Preconditions” level, HFACS identifies the two main contributors shown in Figure 6-4. The first, named Substandard Conditions of Operators, addresses the mental, physiological, and physical states that may have adversely affected the performance of the operators. Specific examples in each category are shown in Figure 6-5. The second contributor is the Substandard Practice of Operators, which can be further divided into the practices of crew resource management and the practices relative to personal readiness. Crew resource management describes the practices of good communication and team coordination (i.e., preparedness of the team), whereas personal readiness refers to mental and physical preparedness of individual team members. Figure 6-5 shows examples for these two subcategories.



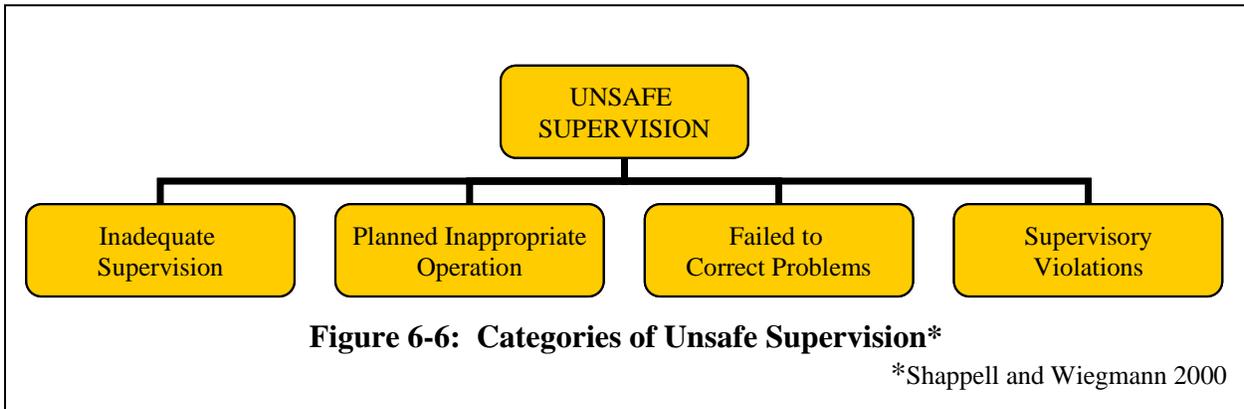
<b>SUBSTANDARD CONDITIONS OF OPERATORS</b>	<b>SUBSTANDARD PRACTICE OF OPERATORS</b>
<p><b>Adverse Mental States</b></p> <ul style="list-style-type: none"> <li>• Channelized attention</li> <li>• Complacency</li> <li>• Distraction</li> <li>• Mental fatigue</li> <li>• Get-home-itis</li> <li>• Haste</li> <li>• Loss of situational awareness</li> <li>• Misplaced motivation</li> <li>• Task saturation</li> </ul> <p><b>Adverse Physiological state</b></p> <ul style="list-style-type: none"> <li>• Impaired physiological state</li> <li>• Medical illness</li> <li>• Physiological incapacitation</li> <li>• Physical fatigue</li> </ul> <p><b>Physical/Mental Limitation</b></p> <ul style="list-style-type: none"> <li>• Insufficient reaction time</li> <li>• Visual limitation</li> <li>• Incompatible intelligence/aptitude</li> <li>• Incompatible physical capability</li> </ul>	<p><b>Crew Resource Management</b></p> <ul style="list-style-type: none"> <li>• Failed to back-up</li> <li>• Failed to communicate/coordinate</li> <li>• Failed to conduct adequate brief</li> <li>• Failed to use all available resources</li> <li>• Failure of leadership</li> <li>• Misinterpretation of traffic calls</li> </ul> <p><b>Personal Readiness</b></p> <ul style="list-style-type: none"> <li>• Excessive physical training</li> <li>• Self-medicating</li> <li>• Violation of crew rest requirement</li> <li>• Violation of bottle-to-throttle requirement</li> </ul>

**Figure 6-5: Examples of Preconditions of Unsafe Acts\***

\* Shappell and Wiegmann, 2000

**Unsafe Supervision**

For Unsafe Supervision, HFACS describes four sublevels in Figure 6-6: inadequate supervision, planned inappropriate operations, failure to correct a known problem, and supervisory violations. Inadequate supervision addresses the question of whether the supervisory chain of command made it possible for the individual team members to succeed in terms of oversight, training, guidance, etc. Planned inappropriate operations refer to the decisions that, by reacting to pressures of schedule, operational tempo, cost cutting, etc., places the operation at greater risk of failure. The third subcategory identifies the instances when a supervisor fails to address deficiencies that are known to him or her, for example in individual performance, equipment maintenance, or other areas related to safety and reliability. Supervisory violations identify instances when rules or regulations are purposely violated. Examples in each of these areas are shown in Figure 6-7.



<p><b>Inadequate Supervision</b></p> <ul style="list-style-type: none"> <li>•Failed to provide guidance</li> <li>•Failed to provide operation doctrine</li> <li>•Failed to provide oversight</li> <li>•Failed to provide training</li> <li>•Failed to track qualifications</li> <li>•Failed to track performance</li> </ul> <p><b>Planned Inappropriate Operations</b></p> <ul style="list-style-type: none"> <li>•Failed to provide correct data</li> <li>•Failed to provide adequate brief time</li> <li>•Improper manning</li> <li>•Mission not in accordance with rules/regulations</li> <li>•Provided inadequate opportunity for crew rest</li> </ul>	<p><b>Failed to Correct a Known Problem</b></p> <ul style="list-style-type: none"> <li>•Failed to correct document in error</li> <li>•Failed to identify an at-risk aviator</li> <li>•Failed to initiate corrective action</li> <li>•Failed to report unsafe tendencies</li> </ul> <p><b>Supervisory Violations</b></p> <ul style="list-style-type: none"> <li>•Authorized unnecessary hazard</li> <li>•Failed to enforce rules and regulations</li> <li>•Authorized unqualified crew for flight</li> </ul>
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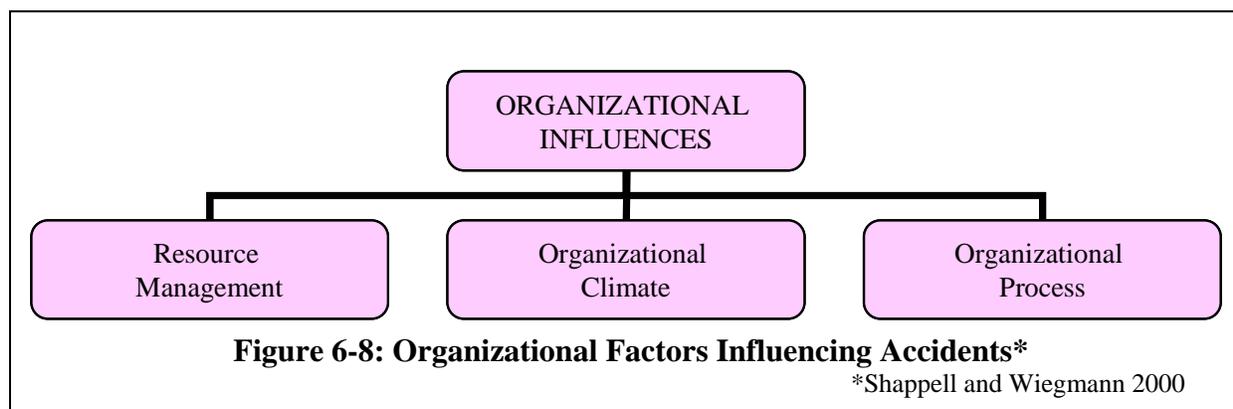
**Figure 6-7: Examples of Unsafe Supervision\***

\* Shappell and Wiegmann, 2000

**Organizational Influences**

HFACS suggests the latent failures that commonly occur in the upper-levels of management and that affect supervisory practices and other controls are issues in resource management, organizational climate, and organizational process as shown in Figure 6-8. Resource management issues are those that relate to policy decisions for the allocation of assets, a classic

example being the tradeoff between safety preservation and cost/profit. Climate refers to the work environments within which personnel perform their functions, and can include communication channels, official policies (e.g., relative to hiring and firing), and unofficial policies (e.g., unspoken rules). The final area is that of organizational process, which describes the ways and methods that tasks are accomplished and work is controlled within the organization. These include standard operating procedures, incentives, operational tempo, and scheduling, among others. Further examples in each of the organizational influences are shown in Figure 6-9.



<p><b>Resource/Acquisition Management</b></p> <p>Human Resources</p> <ul style="list-style-type: none"> <li>•Selection</li> <li>•Staffing/manning</li> <li>•Training</li> </ul> <p>Monetary/budget resources</p> <ul style="list-style-type: none"> <li>•Excessive cost cutting</li> <li>•Lack of funding</li> </ul> <p>Equipment/facility resources</p> <ul style="list-style-type: none"> <li>•Poor Design</li> <li>•Purchasing of unsuitable equipment</li> </ul> <p><b>Organizational Climate</b></p> <p>Structure</p> <ul style="list-style-type: none"> <li>•Chain-of-command</li> <li>•Delegation of authority</li> <li>•Communication</li> <li>•Formal accountability for actions</li> </ul> <p>Policies</p> <ul style="list-style-type: none"> <li>•Hiring and firing</li> <li>•Promotion</li> <li>•Drugs and alcohol</li> </ul> <p>Culture</p> <ul style="list-style-type: none"> <li>•Norms and rules</li> <li>•Values and beliefs</li> <li>•Organizational justice</li> </ul>	<p><b>Organizational Process</b></p> <p>Operations</p> <ul style="list-style-type: none"> <li>•Operational tempo</li> <li>•Time pressure</li> <li>•Production quotas</li> <li>•Incentives</li> <li>•Measurement/appraisal</li> <li>•Schedules</li> <li>•Deficient planning</li> </ul> <p>Procedures</p> <ul style="list-style-type: none"> <li>•Standards</li> <li>•Clearly defined objectives</li> <li>•Documentation</li> <li>•Instructions</li> </ul> <p>Oversight</p> <ul style="list-style-type: none"> <li>•Risk management</li> <li>•Safety programs</li> </ul>
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**Figure 6-9: Examples of Organizational Influences\***

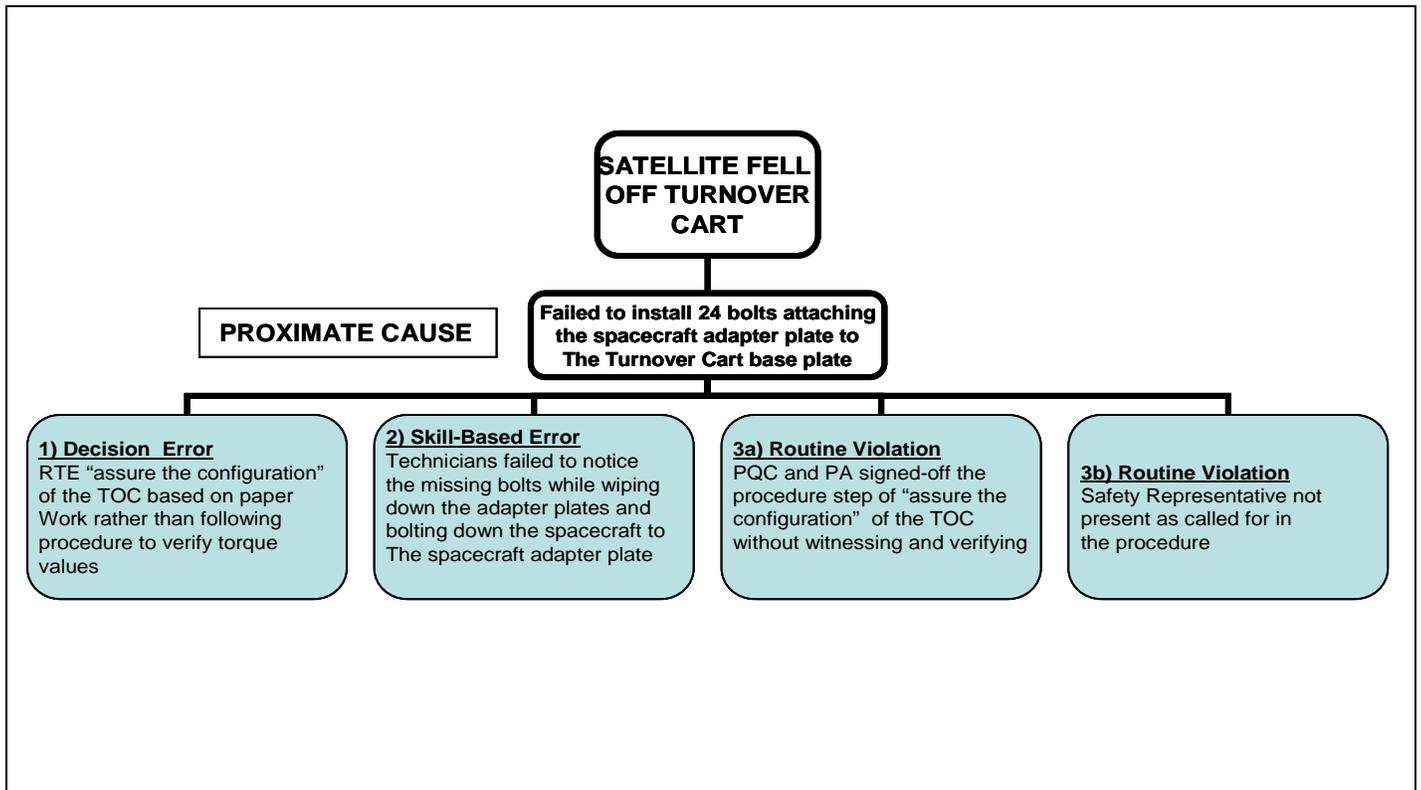
\* Shappell and Wiegmann, 2000

**SECTION 7**

**FINDINGS**

*The proximate cause of The NOAA N-PRIME mishap was the failure of the LMSSC operations team to follow procedures to properly configure the TOC, such that the 24 bolts that were needed to secure the TOC adapter plate to the TOC were not installed.*

The MIB identified root causes along the four levels of active or latent failures as ascribed by the HFACS framework. The supporting findings for these root causes are presented in this section. Figure 7-1 illustrates the Level 1 active failures or unsafe acts leading to the mishap and Figures 7-2, 7-3, 7-4, & 7-5 trace each of the active failures to the three levels of latent failures as ascribed by the HFACS framework. The findings of this analysis are numbered sequentially and are described in more detail in the text that follows.



**Figure 7-1: Level 1 Active Failures or Unsafe Acts Leading to the NOAA N-Prime Mishap**

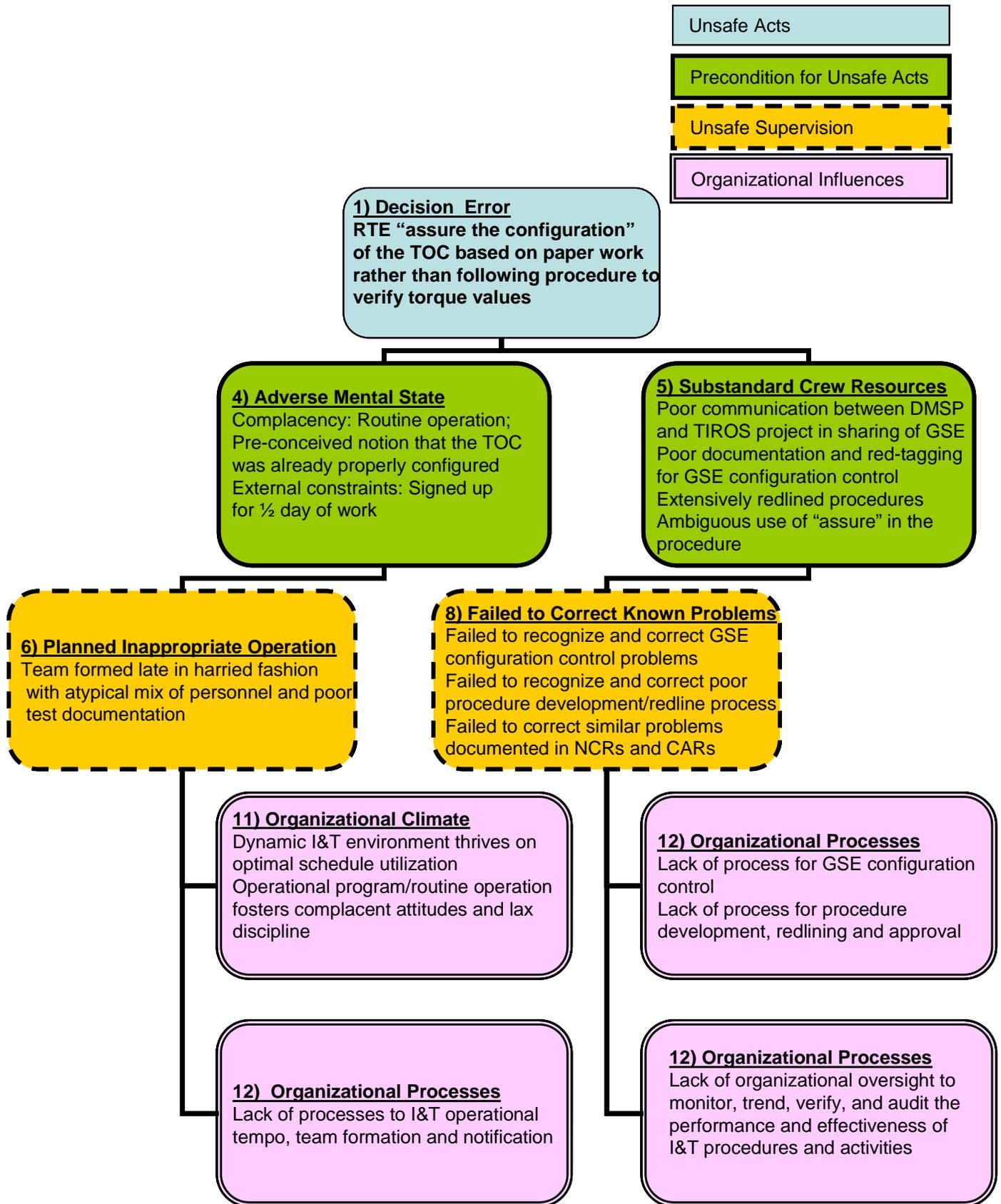


Figure 7-2: Latent Failures Contributory to the Decision Error of the RTE

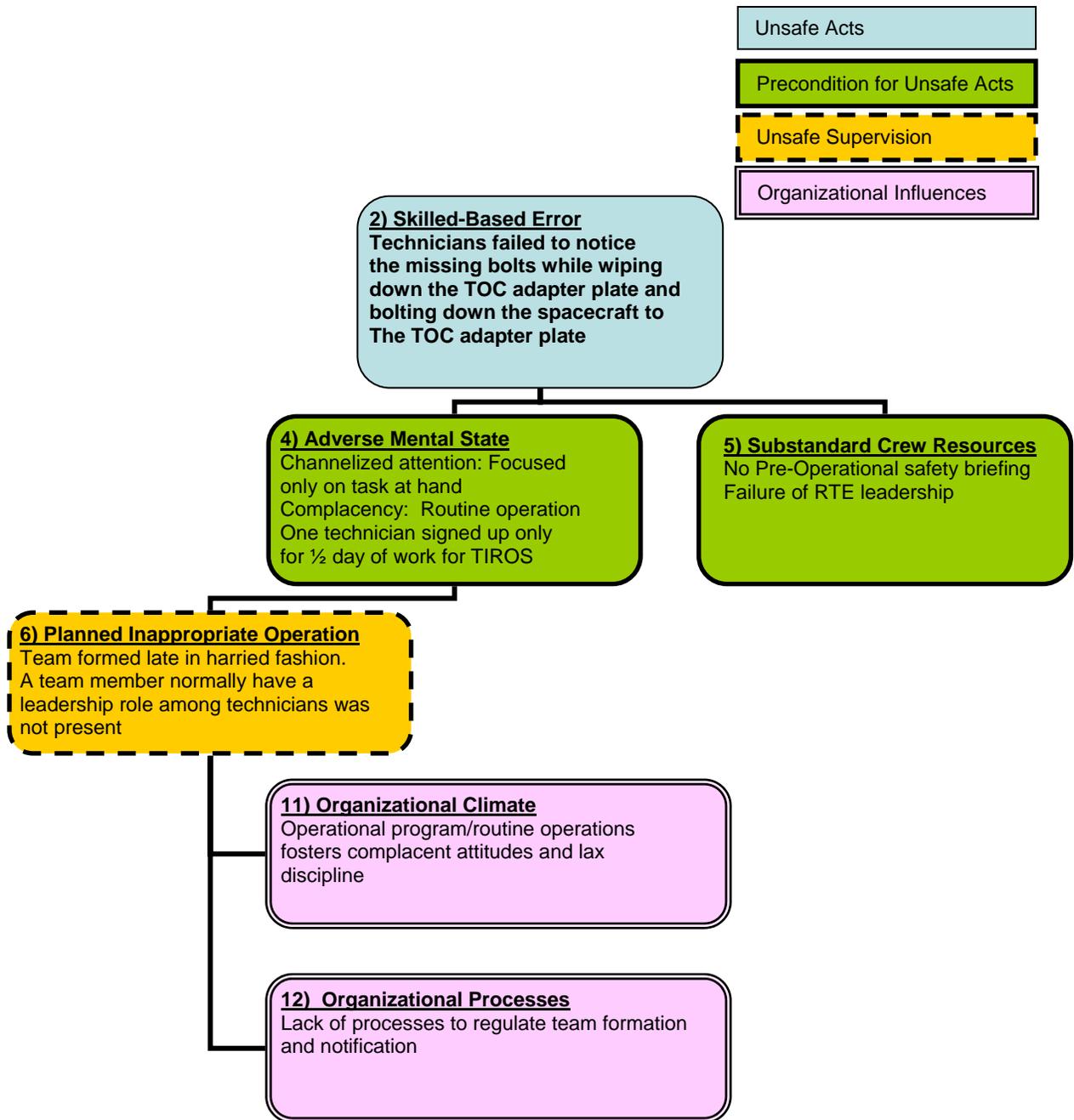


Figure 7-3: Latent Failures Contributory to the Skill-Based Error of the Technicians

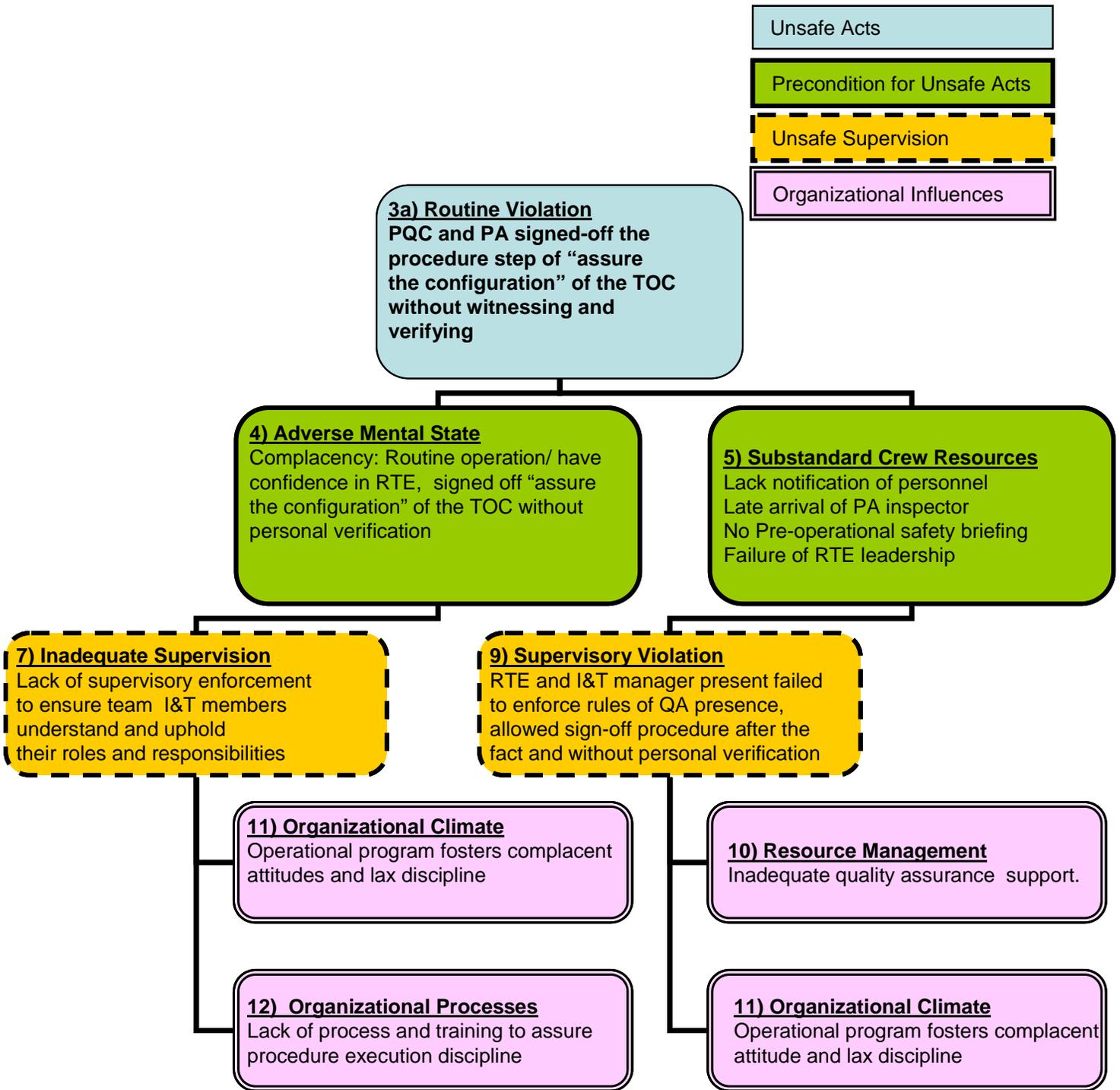
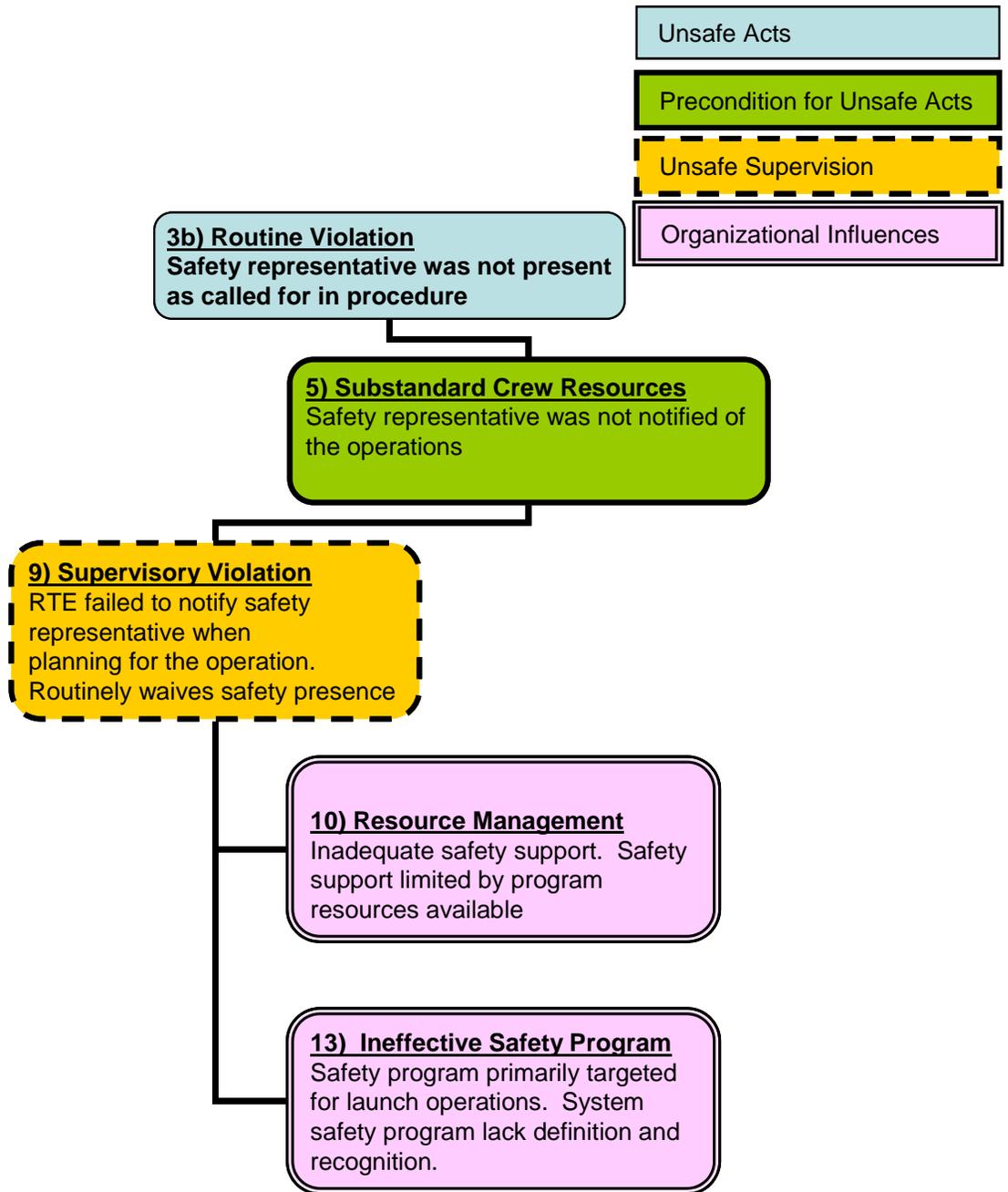


Figure 7-4: Latent Failures Contributory to the Routine Violations of the POC and PA



**Figure 7-5: Latent Failures Contributory to the Absence of Safety Representative**

The following presents the findings for LMSSC, according to the HFACS framework.

### **Level 1: UNSAFE ACTS**

#### **Findings:**

The following unsafe acts are determined to be causal to the NOAA N-PRIME mishap.

- L-1) Decision Error: The RTE decided to “assure” the cart configuration through an examination of paperwork from a prior operation rather than through physical and visual verification. This decision is contrary to the standard operating procedure for this operation and to the RTE’s on-the-job training. The RTE had little actual experience with preparing the TOC for operations and assumed that using paperwork to assure the TOC status was sufficient.

The RTE made a second decision error in dismissing a comment by the Technician Supervisor concerning empty bolt holes during the operation rather than investigating further. The rest of the team, following the RTE’s lead, likewise failed to pursue the apparent warning.

- L-2) Skill-based Error: The technicians who performed the operations of wiping down the TOC adapter plate and bolting down the spacecraft to the adapter plate committed a skill-based error in failing to identify the missing bolts - The technicians, with the exception Technician Supervisor noted above, failed to notice the missing bolts, even though they were working within inches of where the bolts were supposed to be. This happened several times, including when they wiped down the adapter plate with alcohol, lowered the spacecraft to the adapter plate, and bolted it down. This is a skill-based error because the technicians appeared to work in an “automatized” manner. They were narrowly focused on their individual tasks and did not notice or consider the state of the hardware or the operation outside of those tasks. Each member of the crew, when interviewed, commented on the large number of times these procedures had been successfully completed in the past. In addition, each technician commented that the RTE had full authority and responsibility for the operation and that their role was to follow the RTE’s instructions, a culture known to promote the type of channelized attention observed.
- L-3a) Routine Violation: The PQC and the PA signed-off on “assure the configuration” of the TOC procedure step without personally validating the TOC configuration or, in the case of the PA, even being present at the time this step of the procedures was completed during the operation. For both the PQC and the PA, such a validation of the TOC configuration minimally should involve visual verification of the attachment bolts. This investigation uncovered that such violations (e.g., procedure sign-off without personal cognizance) have occurred prior to and during the NOAA N-PRIME mishap.
- L-3b) Routine Violation: The safety representative was not present as called for in the procedure. Again, this investigation determines that such a violation is routine. Operations often proceed without safety representative presence, contrary to specific

procedural requirements. It is unclear whether or not the presence of a safety representative would have averted the mishap. Nonetheless, this is a safety related mishap; a safety representative is expected play a substantial role in prevention of such accidents.

**Statement of Cause:**

*These elements described above led the MIB to conclude that decision and skill-based errors and routine violations by the NOAA N-PRIME I&T team were manifested as a failure to adhere to procedures.*

**Level 2: PRECONDITIONS FOR UNSAFE ACTS**

**Findings:**

At the second level of the HFACS, the MIB found that the preconditions for unsafe acts that were present at the time of the mishap were twofold: substandard condition of the operators in the form adverse mental states and substandard practices of the operators in the form of substandard crew resources management.

L-4) Adverse Mental States: In the former, adverse mental states, it is apparent that complacency was impairment to many on the team directly performing the operation and to those providing supervision or oversight to this team. Evidence of complacency was seen in both the LMSSC and Government project teams, as the operation was consistently characterized as routine and low risk, even though it involved moving the spacecraft. Also affecting performance the day of the mishap were adverse mental states of channelized attention of the technicians as described above and the feeling of external constraints on the RTE, who only signed on for a half day's duty due to family related constraints. Likewise the DMSP technician was scheduled for a half day's work as he was to support another program in the afternoon. Evidence that the operation proceeded at an accelerated pace was expressed by the majority of the operations team, although the precise reason for the acceleration was varied. It is the MIB's belief that the RTE was anticipating his departure and may have hurried through the procedures.

Another significant adverse mental state that may have affected the outcome of the operation was fatigue of the operators. Although no-one claimed to be fatigued, the operation began during a circadian trough (e.g., 6 am), which is known to degrade performance.

L-5) Substandard Crew Resource Management: The MIB found the substandard practice of operators referred to as substandard crew resource management was also a precondition for the unsafe acts. The MIB found evidence of poor coordination and communication among individuals on the crew:

- a. Sharing of GSE between DMSP and TIROS: It was common practice for the technicians to informally notify each other of the state of the equipment. In the circumstances surrounding this mishap, the DMSP technician who de-configured

the TOC did not communicate his actions to the TIROS technicians or RTE, but he was not required by the procedure to do so. The informal nature of the handling of the GSE does not provide clean, robust hand-offs between operation teams.

- b. Red Tagging of TOC: No real formal communication or documentation process exists for handling the red tagging, repair and maintenance of ground support equipment. Typical aerospace practice for controlling critical GSE requires a logbook to track the TOC configuration, repairs and red tagging for any restricted use. In this particular case, the repair of the cart did not return it to its full capacity—a restriction not communicated beyond the I&T manager (requester of repair) and the Technician Supervisor (repairer).
- c. Formation of ad-hoc operations team: Team members were notified as late as quitting time on Friday that they would be needed for Saturday operations. Some personnel, namely the safety representative and the product assurance inspector, were not notified at all. Furthermore, the original plan was to switch RTE's midway through Saturday operations, as well as having only one of the Technicians for half the day (had to get back to support a DMSP operation). The lead technician that would normally have been a member of the team and that usually "assures" the TOC for this RTE was absent due to his dispute with the RTE that occurred due to the RTE's request to work on the satellite without the proper paper orders
- d. Pre-Operational Safety Briefing: It is standard LMSSC policy, captured in paragraph 3.3.1 of the procedure, to require the RTE to conduct a pre-operational safety briefing for all personnel involved in a test activity. This ensures everyone working on the activity understands what needs to be done and their role in accomplishing the work. From the interviews, it was clear this pre-operational safety briefing was not conducted with the crew as a group, nor was there evidence it was conducted individually. It appears the RTE simply directed the crewmembers in what to do and when they should do it. This was true of the PA Inspector as well, as he did not arrive until after the TOC had been configured by the RTE.
- e. Failure of Leadership: As the operations lead, the RTE failed to exercise proper leadership in preparing for the operation and enforcing procedure execution discipline during the operation, resulting in: late and poor preparation of test documentation, late notification and formation of the crew, lack of notification of safety, late arrival of PA inspector, late notification of government QA representative and failure to properly verify the TOC configuration.
- f. Technological Environment: The MIB found that the technological environment in which the operation was conducted was causal in the mishap. The operating procedures called for the RTE to "configure/assure" the TOC, but was silent on how this procedural step must be accomplished. The procedure did not specify that "assure" must include visual inspection, for instance. In addition, the operations team was utilizing a heavily redlined procedure that required considerable "jumping" from step to step, and had not been previously practiced. The poorly written procedure and novel redlines were preconditions to the decision errors made by the RTE.

**Statement of Cause:**

*It is the Board's finding that the adverse mental states of complacency, external constraints and channelized attention and the practice of poor communication and coordination among the extended operations teams set up preconditions that allowed the NOAA N-PRIME mishap to occur.*

**Level 3: UNSAFE SUPERVISION FACTORS—LMSSC**

**Findings:**

The factors identified in the third level, unsafe supervision that allowed the preconditions and unsafe acts of the previous levels, fall into all four subcategories.

- L-6) Planned Inappropriate Operations: The MIB believes that planning for the lift/turnover operation was hurried and resulted in a hastily formed operations team. The team as constituted for the Saturday morning operation included a Technician Supervisor who was acting as part of the technician crew and the I&T manager who was acting as an observer. It did not include the most experienced lead technician, due to his dispute with the RTE the day before concerning inappropriate requests to work on the satellite without written orders. Although all team members were experienced and competent, this atypical mix of authority among the various roles created dynamics that were not conducive to open discussion and shared responsibility. Moreover, a team member that typically would have a leadership role among the technicians was not present during the operation, as he had had a conflict with the RTE over the hurried nature of the operations the day before. The MIB believes this inappropriate nature of the operation, even though planned, had a clear contribution to the conditions surrounding the mishap. This hastily planned operation was casual to the substandard crew resource management practices described above.
- L-7) Inadequate Supervision: Here, the supervisory inadequacies are related to ensuring that operation team members understand and uphold their assigned roles and responsibilities. The teaming of an RTE, a lead technician, a PA inspector, a government quality assurance representative and other technicians is typical for I&T operations in the aerospace industry. Although the roles and responsibilities of the individuals of this team, i.e., RTE as the operations lead, lead technician as chief operator, and PA inspector as the independent quality assurance agent are generally understood, the dynamics of this team are often governed by the personalities and experiences of the individuals, and the conditions of the operation. For instance, the I&T manager, present at the operation, should have enforced adherence to the procedures. The PA manager should have known who was “watching the shop” when he was on leave, and his designee should have ensured the presence of the safety engineer and quality inspector. The MIB concluded that the lack of clear definition, proper training and reinforcement of the roles and responsibilities of these individuals and their lack of enforcement and support by the supervisory chain are contributory factors to this mishap. Whether it was personality or lack of training, the individuals of the team failed to fulfill their expected roles and

responsibilities. Lax or inadequate supervision was a contributing factor to the adverse mental states described above.

- L-8) Failure to Correct Known Problems: Given the prevalence of some of the problems identified above and through interviews, the MIB concluded that the supervisors failed to recognize and correct these adverse trends. In particular, the PA supervisors allowed routine conduct of operations with PA inspector sign-off after the fact, routine waiving of safety presence and routine late notification of government inspectors. The I&T supervisors allowed routine poor test documentation and routine misuse of procedure redlines. In addition, similar problems and deficiencies have been documented under the contractor's Non-Conformance Report and the DCMA Corrective Action Requests, and the supervisors failed to recognize and correct them effectively. This failure to correct known problem is a direct contributor to the substandard crew resource management practices described above.
- L-9) Supervisory Violations: As discussed above, rules requiring the presence of quality assurance and safety were broken and the procedures for assuring the configuration of the cart were not followed, and not for the first time according to interview statements. The supervisors present, the RTE and the I&T manager, did not act to prevent this or rectify it.

**Statement of Cause:**

*The MIB believes that inappropriate planning, in adequate supervision, failure to correct known problems, and supervisory violations by LMSSC resulted in improper staffing, poor process discipline and disregard for rules during the operation. These factors at the supervision level not only did not prevent the conditions or acts that led to the mishap but actively promoted them*

**Level 4: ORGANIZATIONAL INFLUENCES- LMSSC**

**Findings:**

Organizational influences in the Lockheed Martin Corporation that were at work in the NOAA N-PRIME accident include issues in resource management, climate, and processes.

- L-10) Resource Management: The MIB observed an inadequate emphasis on safety within the TIROS program. Few resources are allocated to this function and few requirements for safety oversight exist. Further, little programmatic supervision was provided for the safety representatives. A shrinking of the quality assurance activity was also observed as the program work diminished, with three inspectors now being shared between the TIROS and DMSP projects. In these two key oversight elements, LMSSC failed to provide the appropriate emphasis and corresponding resources.

- L-11) Organizational Climate: The organizational climate in the I&T domain is dynamic and requires flexibility and agility. Last minute changes in schedule, late notification of personnel to support activity changes and weekend work are typical. However, within POES/TIROS program, an operational program with 14 spacecraft launched, the I&T operations associated with the two remaining spacecraft have become routine. This perception was shared by almost everyone the MIB interviewed. Though difficult to establish clear linkages, the MIB nonetheless believes that the dynamics of the I&T function engendered an environment that led to complacent and overconfident attitudes toward routine operations and ultimately, reduced process discipline and vigilance on the part of the crew.
- L-12) Organizational processes: The final organizational influence the MIB felt adversely affected the outcome of the operation was the lack of established and effective process guidelines and safeguards for project and program operations. Key processes that were found to be inadequate include those that regulate operational tempo, operations planning, procedure development, use of redlines, and GSE configurations. For instance, the operation during which the mishap occurred was conducted using extensively redlined procedures. The procedures were essentially new at the time of the operation - that is, they had never been used in that particular instantiation in any prior operation. The re-written procedure had been approved through the appropriate channels even though such an extensive use of redlines was unprecedented. Such approval had been given without hazard or safety analyses having been performed. Similarly, trends in prior incidences of non-conformances or mishaps that were the result of wrongly implemented or poorly written procedures were not periodically examined by the organization; lacking is the organizational oversight to monitor, verify and audit the performance and effectiveness of the procedures and activities. These deficient organizational processes led to the inappropriately planned operation and failure to correct known problems.
- L-13) Ineffective Safety Program: Finally, throughout this investigation, the MIB finds the system safety program to be very ineffective. The current safety program is primarily targeted for launch site safety. The system safety program lacks definition and organizational recognition.

**Statement of Cause:**

*The MIB finds that the limited resources and emphasis dedicated to quality assurance and system safety; an unhealthy organizational climate that bred complacency and overconfidence; and the lack of effective operations and oversight processes were the root causes of the mishap. The MIB finds the LMSSC system safety program, in particular, to be ineffective.*

Following HFACS framework, the following identifies the findings for the government. Given the government provides an oversight function, only the unsafe oversight and organizational influences of the HFACS levels are analysis.

### **Level 3: UNSAFE OVERSIGHT FACTORS-Government**

#### Findings:

The role and responsibilities of the Government in providing oversight and guidance to contractor project execution and operations were examined within the HFACS framework. For the NOAA N-PRIME mishap, the factors identified include Inadequate Oversight and Failure to Correct Known Problems.

- G-1) Inadequate Oversight: In the area of oversight, the MIB found that the government quality assurance and safety oversight at GSFC had become issue driven due to the maturity of the project. Once issues were brought to their attention, the QA/safety personnel worked their resolution but there was very little proactive oversight, audit, inspection, etc. of the LMSSC operations. Procedures were rarely reviewed, non-conformances were not trended, and the GSFC personnel rarely made impromptu inspections of the LMSSC operations.
- G-2) Limited Quality Assurance Oversight: The MIB also believes the change from processing two satellites simultaneously to working on one satellite at a time led to a reduction in DCMA and GSFC QAR support. Although this did not change the number of Government Mandatory Inspection Points (GMIP), the MIB felt that the quality of oversight resources may have been impacted. The most significant piece of evidence indicative of a failed oversight process and barrier to safety problems was the absence of the QAR during the operation that resulted in the mishap. Although his presence may not have prevented the mishap, he inappropriately waived a Mandatory Inspection Point. In practice, the QAR was assumed to have the authority to act as the DCMA representative by the POES Project Office, DCMA, and LMSSC. On the day of the mishap, when LMSSC called the QAR, he told them to proceed and he was on his way in. By effectively waiving the requirement to witness the spacecraft lift, he failed to enforce a DCMA requirement.
- G-3) Limited System Safety Oversight: The MIB found that the government provides very limited system safety oversight. Again, safety oversight is predominantly targeted for launch site operations.
- G-4) Failure to Correct Known Problems: Supporting the Failure to Correct Problems factor, the MIB was told that the some of the problems associated with procedure discipline and safety and program assurance oversight were known to the in-house Government QAR but were not communicated to the NASA project. Given his prior association with the LMSSC project personnel, the Government QAR tended to work the problems directly with LMSSC rather than pass on the information. In some cases, known problems were not addressed due to familiarity with the LMSSC personnel and reliance on personal relationships. Given the prevalence of some of the contractor deficiencies identified in this investigation, however, it is the MIB's assessment that these deficiencies constitute problems which the government in-plant representative, DCMA, and the GSFC QA/Safety function should have recognized and demanded correction. In particular,

these deficiencies have been identified and recorded through the contractor NCRs and the DCMA CARs.

**Statement of Cause:**

*Both the in-plant government representation and the GSFC QA/safety function failed to provide adequate oversight to identify and correct deficiencies in LMSSC operational processes, and thus failed to address or prevent the conditions that allowed the mishap to occur.*

**Level 4: ORGANIZATIONAL INFLUENCES—GOVERNMENT**

**Findings:**

Resource management, organizational climate, and processes within the government are also implicated as factors for the mishap.

- G-5) Resource Management: the GSFC project, in working to deal with a declining workload and resources, allowed and even encouraged trade-offs between the schedules, staffing and milestones for the two remaining satellites in the POES (TIROS) project. These constant and rapid trade-offs exacerbated the already fast operational tempo of the LMSSC I&T team. The MIB believes these frequent trade-offs may have inadvertently provided incentives to LMSSC to take on additional risk. Resource management also appears to be an issue in other areas: the project has very few resources in the safety area, and the assurance manager recently took on an additional project, thus reducing his time on POES (TIROS). Although in this latter case, an additional quality engineer was added, the level of experience of this resource was below that of the assurance manager. Insufficient resources also led DCMA to cut back support for weekends. It is the MIB's assessment that the current on-site DCMA and quality assurance staffing levels are insufficient to provide effective coverage.
- G-6) Organizational climate was found to be an issue, primarily in the government on-site structure. There is no Project in-plant civil servant government presence. The Project in-plant government representatives (one in quality assurance, two in I&T) were past employees of LMSSC and were hired as outside contractors by the GSFC Project Office. With a wealth of relevant experience and familiarity with the inner workings of the LMSSC organization, these employees are well qualified for their positions technically. However, their past associations with the company might precipitate undue complacency due to familiarity. In particular, the QAR was formerly the Product Assurance Manager for this facility. His experience and familiarity with the LMSSC staff clearly might facilitate problem resolution as they are encountered. This runs the risk however of relaxing the proper checks and balances of the independent quality assurance function, such as overlooking problems by not properly reporting deficiencies; placing inappropriate confidence in former colleagues; or skipping inspection requirements. As a particular example in this mishap, the QAR waived his presence at the spacecraft lift. The MIB also has misgivings about organizational climate engendered by the complacent attitudes toward routine operations. In this instance, the contractor's emphasis toward

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schedule utilization and casual disregard for process and personal discipline are reflected by the government's lax and casual oversight

- G-7) Organizational Processes: The MIB found no effective guidelines regarding the government's oversight role in I&T operations planning, procedure development, and procedure execution discipline. The coordination between contractor and DCMA/QAR in preparing for this operation was late and confusing. It is not clear the role that the government should play in the review of procedures and test documentation and the enforcement of contractor procedure execution discipline. The MIB found no effective process in place to follow up on closure of DCMA generated Corrective Action Requests (CARs), SAC generated audit deficiencies and action items from an external review (TIROS Anomaly Review/Appendix L). Although the POES Project and the contractor track and trend closure of contractor generated Non-Conformance Report (NCRs) for timeliness, there is no process in place to analyze and trend NCRs for cause and to identify systemic problems. Likewise lacking is the government organizational oversight to monitor, verify and audit the performance and effectiveness of the I&T processes and activities.
- G-8) The Government System Safety Program placed an overemphasis on launch site safety and inadequate in-plant system safety. The LMSSC Safety Plan had not been updated for many years, with little or no change since the move to LMSSC at Sunnyvale. In addition, no Operational Hazard Analysis or similar analysis of potential in-plant hazards was ever performed. Such an analysis would identify the procedures and operations that are considered hazardous and appropriate mitigation measures implemented.
- G-9) The MIB found the DCMA CAR Assessment and Reporting Process and other DCMA audit processes to be deficient in identifying troubling trends in the LMSSC facility. Review of CARs indicated repeated requirement violations and bypassing of Mandatory Inspection Points by the contractor. The DCMA Technical Assessment Group (TAG) facility audits, the DCMA annual safety audits, and the DCMA facility summary reports of CARs prior to the mishap, however, all indicated a healthy facility environment, with no noteworthy problems reported.

### Statement of Cause:

*The MIB finds inadequate resource management, an unhealthy organizational climate and the lack of effective oversight processes led to inadequate QA and system safety oversight, casual oversight discipline, and inadequate follow-up to monitor contractor performance deficiencies within the I&T environment.*

Tables 7-1 and 7-2 summarize the findings for LMSSC and the Government.

**Table 7-1: Findings Summary (LMSSC)**

**UNSAFE ACTS**

- L-1) Decision error: The RTE committed a “decision error” by not following procedures.
- L-2) Skill based error: Technicians committed “skill based error” by not noticing the missing bolts while wiping down TOC adapter plate and bolting down the spacecraft.
- L-3a) Routine violation: PQC and PA inspector committed “routine violations” by signing-off on operations without witnessing and verifying TOC configuration.
- L-3b) Routine violation: Safety representative, as required by the procedure, was not present.

**PRECONDITIONS FOR UNSAFE ACTS**

- L-4) Adverse mental states in the forms of “channelized attention”, “complacency”, and “external constraints” resulted in an accelerated pace of operations and procedure execution.
- L-5) Substandard crew resources included poor hand-off between the DMSP and TIROS Projects regarding the TOC, poor red-tagging process for GSE, late identification of personnel to work Saturday, lack of pre-operational safety briefing, and lack of leadership on the part of the RTE.

**UNSAFE SUPERVISION**

- L-6) Planned inappropriate operation: The team was formed late in a harried fashion with an atypical mix of personnel and poor test documentation.
- L-7) Inadequate supervision was manifested in the lack of clear definition and enforcement of roles and responsibilities among the team individuals, consequently individuals failed to fulfill their expected roles and responsibilities.
- L-8) Failure to correct known problems was a supervisory failure to correct similar known problems. PA supervisors routinely allowed PA inspector sign-off after the fact. I&T supervisors routinely allowed poor test documentation.
- L-9) Supervisory violation was committed by repeatedly waiving required presence of quality assurance and safety and bypassing Government Mandatory Inspection Points.

**ORGANIZATIONAL INFLUENCES**

- L-10) In Resource management, MIB observed inadequate emphasis on safety, and inadequate quality assurance support to provide effective coverage.
- L-11) The Organization climate in the I&T domain with an operational program has engendered an environment that led to complacent and overconfident attitudes toward routine operations.
- L-12) Lack of effective “Organizational processes” in the form of guideline and safeguards to regulate the I&T environment. Lack of organizational oversight to monitor, verify and audit the performance and effectiveness of the procedures and activities.
- L-13) Ineffective System safety program.

**Table 7-2: Findings Summary (Government)**

**UNSAFE OVERSIGHT**

- G-1) Inadequate Oversight: The government quality assurance and safety provided inadequate oversight. Oversight function became issue driven. Procedures rarely reviewed; non-conformances not trended; rarely make impromptu inspections.
- G-2) Inadequate QA Oversight: In substituting for the DCMA, the QAR failed to enforce a Government Inspection Point by failing to enforce his presence at the operation..
- G-3) Limited System Safety Oversight: Government has very limited safety oversight.
- G-4) Government “Failed to correct known problems”, such as PA signoff after the fact and poor test documentation.

**ORGANIZATIONAL INFLUENCES**

- G-5) Deficient “Resource management” include: rapid trade-offs between the schedules, staffing and milestones for the two remaining satellites exacerbated the already fast operational tempo of the LMSSC I&T team; lack of resources in the safety area; insufficient DCMA and quality assurance staffing to provide effective coverage.
- G-6) “Organizational climate” factors include: On-site organizational structure of using retired LMSSC employees as government representatives; lax and casual oversight toward an I&T environment with routine operations.
- G-7) Lacks Government oversight guidelines regarding I&T operations planning, procedure development, and procedure execution discipline. Lacks Organizational processes to effectively monitor, verify, and audit the performance and effectiveness of the I&T processes and activities.
- G-8) The Government safety program placed an overemphasis on launch site safety and inadequate in-plant safety.
- G-9) Deficient DCMA CAR assessment and reporting processes.

## SECTION 8

### RECOMMENDATIONS

Although the unsafe act of failure to follow procedures by the individuals of the NOAA N-Prime I&T team was the immediate cause of the mishap, it is the assessment of the MIB that deficiencies at the process, supervisory and organizational levels were contributory factors. These deficiencies within the program are wide in scope and are rooted in failure to follow sound engineering processes and lack of effective supervisory and organizational practices. This section identifies the MIB recommendations to remedy these deficiencies. These recommendations include basic process improvements for procedure development, review and approval; establishment of configuration management for ground support equipment; sensitizing individual, supervisory and organizational awareness to process discipline; and enforcement of rules and regulation through training programs and improvements in organizational structures and practices, for the contractor LMSSC and for the government. Sections 8.1 and 8.2 present the MIB recommendations for LMSSC and the government, respectively.

#### 8.1 Recommendations-LMSSC

Natural fallout of the HFACS analysis exercise is the linkage between the findings or deficiencies among the four levels of human failures. With active or latent failures (i.e., lack of effective safeguards), the HFACS provides a comprehensive framework to categorize these deficiencies and to formulate intervention strategies. The following present the MIB recommendations for the LMSSC organization and correlate the associated findings under the HFACS framework.

- 1) Provide a formal training program for certifying all test conductors and for training all I&T personnel in their roles and responsibilities. Provide periodic refresher training to reinforce these roles and responsibilities

This recommendation addresses the deficiencies identified in findings L-1, 2, 3a, & 4.

As the immediate cause of the mishap, individual process discipline must be restored at the organizational level. In particular, organizational practices must be established to reinforce the role and responsibility of contractor and government inspectors as independent verification agents, serving as a safety net for the individuals executing the procedure. Procedure execution discipline must be enforced and operational signoff without personal cognizance must be banned. This recommendation directly addresses the organizational deficiency that the lack of clear definition of the roles and responsibilities for the individuals in the I&T structure was a significant causal factor leading to the decision errors and routine violations of the PQC and the PA. Periodic refresher training would serve to reinforce these roles and responsibilities and to dispel any complacency from settling in over time.

To serve in the leadership role, the test conductor or RTE must be certified to have the appropriate qualifying experience as well as the supervisory discipline and training. As test

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conductor, the RTE must be a role model of process discipline and safety consciousness for the rest of the team.

Central to this training is the emphasis that safety is everyone's responsibility, where there is no such thing as a routine operation from the safety perspective. Skill based errors (e.g., not noticing the missing bolts) as committed by the technicians were preventable. While focus must be exercised to perform the task at hand, circumspection must also be exercised to discern extraordinary signs of hazard or other untoward events.

- 2) Provide supervisory training to promote an active supervisory role in identifying, monitoring and correcting poor processes discipline and other deficiencies.

This recommendation addresses the deficiencies identified in findings L-6, 7, 8, and 9

Given the prevalence of the deficiencies identified through this investigation, it is the MIB's assessment that the supervisors were aware of these deficiencies and failed to correct them. The PA and I&T supervisory chain should take a more active role in monitoring and correcting the deficiencies identified by the Non-Conformance Reports as well as the Corrective Action Requests. Inadequate supervision permitted the planning of an inappropriate operation in a hurried fashion with an atypical crew mix and poor documentation. In addition, supervisory violation was committed in failure to properly notifying the safety representative and quality assurance support as required. Supervisors must set an example and enforce standards of process discipline. This training should address all supervisory deficiencies identified.

- 3) Establish effective process guidelines and safeguards to regulate the I&T environment. Process guidelines and safeguards should be developed for operations planning, procedure development, redlining, procedure execution discipline, GSE configuration management.

This recommendation addresses the deficiencies identified in findings L-5, 6, 11 & 12.

The basis of poor crew resources management (finding L-5), planned an inappropriate operation (finding L-6), and poor process discipline due to adverse organizational climates (L-11) are the results of deficient processes and their enforcement. This recommendation addresses the organizational deficiency that the lack of effective operational processes for the I&T environment led to inappropriately planned operations and specific poor I&T practices and disciplines. Effective guidelines and safeguards should serve to discourage tendencies toward compromising process discipline under the influence of the dynamics of an I&T environment and the complacency of an operational system.

- a) Operations Planning- Establish clear guidelines for the assembly and notification of an I&T team in support of an operation. The team must be of proper make-up, experience and training.
- b) Procedure Development- A major MIB finding is the lack of sound procedure development, redlining and execution practices. The MIB recommends that all procedures be reviewed for clarity and completeness, to include:

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- Define intended actions for ‘assure’, ‘verify’ and other interpretable terms.
  - Conduct a systematic review and identification of hazards and safety critical operations. Perform an operational FMEA as part of this process.
  - Uniquely identify hazardous and critical operations, for the overall procedure and specific steps.
  - Provide emergency instructions when operations are capable of causing personnel injury or equipment damage if not expeditiously shutdown, safed, or secured should a malfunction occur.
  - Include a mandatory pre-operational briefing with a checklist and step in the procedure.
  - Provide verification that all constraints for an operation are closed with a separate step in the procedure.
  - For repeatable procedures, provide a sign off/buy off for each step.
- c) Redlining- The MIB recommends a review of the redlining process and training of personnel on purpose and usage, to include:
- Clarify when redlines are appropriate.
  - New procedures should not be developed as a redline.
  - Sign off on redlines should require review by other than the operators conducting or witnessing the operation.
- d) Procedure Execution Discipline- The MIB recommends improvements in procedure execution discipline, to include:
- Ban operation signoff without personal cognizance
  - Ensure procedure instructions are clearly communicated and understood by all personnel directly involved with the operation
  - PA, Safety and Government sign off should not be allowed to be waived without approval of Project Office
- e) GSE Configuration Management- Establish an effective GSE configuration management program to provide: a) centralized GSE configuration management, maintenance and repair record keeping; b) verification of maintenance and repair for GSE; and c) centralized control of GSE shared by different programs..
- 4) Review and staff PA and safety support according to requirements. It is the MIB’s assessment that the current PA and safety staffing level is insufficient to provide effective coverage.

This recommendation addresses the organizational deficiency of resource management identified in finding L-10.

- 5) Establish an effective safety program with a well-defined system safety policy and mandatory requirements. Safety awareness must be promoted to all levels of the organization through a training program or a training module within other applicable training programs. Safety needs to be an integral part of the organization and operation at Sunnyvale.

This recommendation addresses the deficiency identified in finding L-3b and L-13.

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This recommendation addresses the deficiency that at all four levels of the HFACS analysis, some aspects of the lack of safety awareness, support, supervision, guidelines, and requirements were identified as contributing factors to this mishap. The current safety program is ineffective as it is loosely structured, lacks definition and the level of support is resource dependent.

- 6) Establish an effective monitoring, trending, verification and audit program to manage the performance and deficiencies of the I&T activities.

This recommendation addresses the deficiencies identified in finding L-8&12.

This recommendation addresses the lack of effective organizational oversight to manage the performance and risks associated with the I&T environment. In particular, problems and deficiencies identified by the contractor and the government were not examined for effective closure. Though problems that had significant consequences were addressed promptly (as in this mishap, the LMSSC AIT was convened promptly), there is not an effective program to track, examine, categorize and trend the nature and closure of the contractor identified non-conformance reports (NCRs) or the DCMA generated Corrective Action Requests (CARs). These NCRs, CARs as well as other lesser accidents and near misses should be monitored, trended and evaluated for clues of foreshadowing systemic problems. This program should also monitor and track the closure of actions, deficiencies, and recommendations resulted from outside audits and reviews, such as this mishap investigation, the TIROS Anomaly Review, and the Supplier Assurance Contract (SAC) assessments.

Complementing the monitoring and trending program, an effective program must be established to verify and audit compliances to LMSSC Command Media or other established processes or guidelines. To counteract complacency and lapses into poor practices, periodic audits of processes and activities must be conducted to prevent deviation from command media and to demonstrate compliance to new requirements.

- 7) Closed Circuit Video Monitoring- It is the MIB's assessment that closed circuit video monitoring within the I&T area is an effective aid for promoting process discipline, improving safety awareness, facilitating effective oversight, and investigating mishaps. Closed circuit video monitoring within the I&T area is recommended.

This recommendation addresses deficiencies identified in findings L-7 and L-12.

- 8) Establish a training program to disseminate lessons learned from this and other mishaps. This program would constitute an important supplement to safety awareness. This also constitutes and the organizational oversight

This recommendation addresses the deficiencies identified in findings L-1, 2, 3, 4, 12.

Table 8-1 summarizes the MIB recommendations for LMSSC and the associate findings that the recommendation is intended to remedy.

<b>Table 8-1: Summary of Recommendation for LMSSC and Corresponding Findings</b>		
<b>Recommendations</b>		<b>Findings</b>
1)	Provide a formal training program for certifying all test conductor and for training all I&T personnel of their roles and responsibilities. Provide periodic refresher training to reinforce these roles and responsibilities	L-1) RTE decision error L-2) Technician skill-based error L-3a) PA and PQC routine violations L-4) Adverse mental states
2)	Provide supervisory training to promote an active supervisory role in identifying, monitoring and correcting poor process discipline and other deficiencies.	L-6) Planned inappropriate operation L-7) Inadequate supervision L-8) Failure to correct known problem L-9) Supervisory violation
3)	Establish effective process guidelines for regulating the I&T environment, including operations planning, procedure development, redlining, procedure execution discipline, and configuration management	L-5) Substandard crew resources management L-6) Planned inappropriate operation L-11) Organizational climate L-12) Lack of organizational process to regulate the I&T environment
4)	Review and staff PA and safety personnel support according to requirements.	L-10) Resource management: limited quality assurance and safety support
5)	Establish an effective safety program with a well-defined system safety policy and mandatory requirements. Safety awareness must be promoted to all levels of the organization through a training program or a training module within other applicable training programs.	L-3b) Routine violation: absence of safety 11) Organizational climate 13) Ineffective safety program
6)	Establish an effective monitoring, trending, verification and audit program to manage the performance and deficiencies of the I&T activities.	L-8) Failure to correct known problems L-12) Lack of organizational processes to monitor, verify and audit the performance and effectiveness of the procedures and activities
7)	Closed Circuit Video Monitoring as an aid to supervision and promote performance monitoring	L-7) Inadequate supervision L-12) Lack of organizational processes to monitor, verify and audit the performance and effectiveness of the procedures and activities
8)	Establish a training program to disseminate lessons learned from this and other mishaps	L-1) RTE decision L-2) Technician skill-based errors L-3) PQC and PA routine violations L-4) Adverse mental states L-12) Organizational oversight

## 8.2 Recommendations-Government

The lack of effective government supervision or oversight cannot be overlooked in this mishap. In particular, as with the contractor quality inspectors, the roles and responsibilities of government inspectors as independent verification agents must be reinforced. The MIB recommends the following to improve the government oversight effectiveness:

- 1) Provide a dedicated, full time government in-plant representative as indication of commitment and support. Given the common work-areas and equipment, the MIB recommends this individual be shared with the DMSP program. It would be left to the discretion of the project office whether this individual would be a civil servant assigned from the project office, or a civil servant drawn from the DCMA staff. Since this individual will oversee all in-plant contract staff, the MIB recommends this position be evaluated for a higher grade level than is currently authorized.

This recommendation addresses the deficiency identified in finding G-6.

This recommendation addresses the government in-plant organizational structure weakness of having only former LMSSC contract employee on staff. A civil servant in-plant representative, serving as the lead for the in-plant staff, would strengthen the authority of the office and would provide more effective supervision of the in-plant staff.

- 2) Establish and document clear roles and responsibilities for DCMA and the contractor in-plant representatives. Review and revise DCMA Letter of Delegation and the government in-plant representative Letter of Assignment.

This recommendation address the deficiencies identified in finding G-2 and G-6.

This recommendation addresses the government in-plant structure's apparent lack of a clear definition of the roles and responsibilities of the in-plant representative as an independent government quality assurance agent, and in particular as a DCMA substitute. In the instance of this mishap, the QAR failed to be fulfill his obligation as the DCMA representative and failed to be present at the spacecraft lift operation.

- 3) NASA should provide sufficient resource for DCMA to effectively implement the plan to fulfill the Letter of Delegation. The NASA Project should provide sufficient on-site quality assurance support to effectively implement the plan to fulfill the Letter of Assignment. It is the MIB's assessment that the current on-site DCMA and quality assurance staffing levels are insufficient to provide effective coverage.

This recommendation addresses the deficiency identified in finding G-5.

This recommendation addresses the organizational deficiency of resource management, and consequently providing inadequate oversight.

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- 4) Establish effective oversight guidelines and safeguards for the I&T environment. Effective oversight guidelines should be developed for operations planning, procedure development, and procedure execution discipline.

This recommendation addresses the deficiencies identified in findings G-1, 4, 6 and 7.

Effective government oversight guidelines should be established to eliminate the current practice of issue driven mode of oversight (finding G-1), to correct known contractor problems (finding G-4), and to counterbalance the dynamics of the I&T culture and the complacency of an operational system (finding G-6).

- a) Operations Planning- Establish government oversight guidelines relative to the government's role in operations planning:
    - Clarify and establish guidelines for government notification of operations planning activities and review of test documentation.
    - Establish clear communications protocol between the contractor and government of planned activities, schedule and support requirements. There was clear indication of schedule confusion relative to this mishap.
  - b) Procedure Development- Establish government oversight guidelines relative to review of procedures:
    - Clarify and establish guidelines for government review of procedures.
    - Institute government review and sign off of critical procedures.
  - c) Procedure Execution Discipline- Enforce procedure execution discipline:
    - Ban operation signoff without personal cognizance.
    - Government inspections should not be waived without the consent of the government project System Assurance Manager (SAM)
- 5) Establish an effective safety oversight program. Ensure that the System Safety Program Plan is updated and hazard analysis is performed. Increase safety oversight and provide safety training.

This recommendation addresses the deficiencies identified in findings G-3, 5 and 8.

The government has the same deficiency as the contractor in the lack of an effective system safety oversight program. The government must set the pace in safety consciousness. It is not acceptable that safety support is tailored to resources available.

- 6) Coordinate with the contractor to implement an effective oversight program to monitor, trend, verify and audit the contractor performance and deficiencies.

This recommendation addresses the deficiencies identified in findings G-4 and 7.

The government should coordinate with the contractor to implement an effective program to track, examine, categorize and trend the nature and closure of the contractor identified non-

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conformance reports (NCRs) or the DCMA generated Corrective Action Requests (CARs). These NCRs, CARs as well as other lesser accidents and near misses should be monitored, trended and evaluated for clues of foreshadowing systemic problems. This program should also monitor and track the closure of actions, deficiencies and recommendations from outside audits and reviews, such as this mishap investigation, the TIROS Anomaly Review, and the Supplier Assurance Contract (SAC) assessments.

The government should audit contractor process and procedures to assure contract compliance and compliance with local requirements.

- 7) DCMA to evaluate the effectiveness of their assessment processes that seem to have missed identifying unhealthy trends and potential systemic problems. Formulate corrective measures.

This recommendation addresses the deficiency identify in finding G-8.

Review of CARs indicated repeated requirement violations and bypassing of Mandatory Inspection Points by the contractor. The DCMA Technical Assessment Group (TAG) facility audits, the DCMA annual safety audits, and the DCMA facility summary reports of CARs prior to the mishap, however, all indicated a healthy facility environment, with no noteworthy problems reported.

- 8) Periodic independent reviews should be conducted to review Project status and performance.

This recommendation addresses the deficiencies identified in finding G-7.

This is just another aspect of providing oversight to an operational program. For an operational project such as POES, without the vigorous review schedule and process of developmental programs, such periodic reviews are essential to provide an independent assessment of performance and to combat lapses of complacency.

Table 8-2 summarizes the MIB recommendations for the government and the associate findings that the recommendation is intended to remedy.

**Table 8-2: Summary of Recommendation for the Government and Associate Findings**

<b>Recommendations</b>		<b>Findings</b>
1)	Provide a dedicated, full time government in-plant representative as indication of commitment and support.	G-6) Organizational structure of using retired LMSSC personnel as government representative
2)	Establish and document clear roles and responsibilities for the contractor in-plant representatives. Revise Letter of Delegation for DCMA and Letter of Assignment for QAR.	G-2) Inadequate QA oversight: Absence of QAR at the operation. G-6) Organization structure: Lack of clear definition of roles and responsibility of the QAR.
3)	Provide sufficient resource for DCMA to fulfill the Letter of Delegation and for the on-site government support to fulfill the Letter of Assignment	G-5) Resource management: Insufficient DCMA and on-site QA to provide effective coverage.
4)	Establish effective oversight guideline for I&T operations planning, procedure development, and procedure execution discipline.	G-1) Inadequate oversight G-4) Failure to correct known contractor problems. G-6) Adverse organizational climate G-7) Lack of government oversight guidelines regarding I&T operations planning, procedure review, and procedure execution discipline.
5)	Establish an effective safety oversight program. Ensure Safety Program Plan is updated and hazard analysis is performed. Increase safety oversight and provide safety training.	G-3) Limited safety oversight G-5) Lack of resources in safety G-8) Ineffective safety program
6)	Coordinate with the contractor to implement an effective oversight program to monitor, trend, verify and audit the contractor performance and deficiencies.	G-4) Failure to correct known problems G-7) Lack of organizational process to monitor, verify and audit the performance and effectiveness of the procedures and activities.
7)	DCMA to evaluate the effectiveness of their assessment processes and formulate corrective measures.	G-9) Deficient DCMA CAR assessment and reporting process
8)	Periodic independent reviews should be conducted to review Project status and performance	G-7) Lack of organizational process to monitor, verify and audit the performance and effectiveness of the procedures and activities.

**SECTION 9**

**OBSERVATIONS**

**Proprietary Information**

**SECTION 10**

**ACRONYMS LIST**

AESOP	Assignment, Equipment, Situation, Obstacle, and Personnel
AIT	Accident Investigation Team
ARC	Ames Research Center
C/A	Corrective Action
CAR	Corrective Action Request
CM	Configuration Management
DCMA	Defense Contractor Management Agency
DMSP	Defense Meteorological Satellite Program
ESD	Electrostatic Discharge
FMEA	Failure Mode Effects Analysis
GMIP	Government Mandatory Inspection Points
GOES	Geostationary Operational Environmental Satellite
GOVT	Government
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HFACS	Human Factors Analysis and Classification System
I&T	Integration and Test
LEO	Low Earth Orbit
L/V	Launch Vehicle
LMC	Lockheed Martin Corporation
LMSSC	Lockheed Martin Space Systems Company
LOO	Log Of Operations
MH	Mechanical Handling
MHS	Microwave Humidity Sounder
MIP	Mandatory Inspection Point
MIB	Mishap Investigation Board
MOU	Memorandum of Understanding
MSPSP	Missile System Pre-launch Safety Package
NCR	Non-Conformance Report
NESDIS	National Environmental Satellite, data and Information Service
NOAA	National Oceanic and Atmospheric Administration
NPD	NASA Program Directive
NPG	NASA Program Guideline
PA	Product Assurance
POES	Polar Operational Environmental Satellite
PQC	Product Quality Control
QA	Quality Assurance
QAR	Quality Assurance Representative
QE	Quality Engineer
RTE	Responsible Test Engineer
SAC	Supplier Assurance Contract

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S/C	Spacecraft
SEU	Single Event Upset
SV	Sunnyvale
TAG	Technical Assessment Group
TI	Test Instruction
TI-MH	Test Instruction for mechanical handling procedure
TI-NSET	Test Instruction for setting up spacecraft for electrical testing
TI-PNL	Test Instruction for opening up spacecraft panels 1& 4
TIROS	Television Infrared Observational Satellites
TOC	Turnover Cart
TP	Test Procedure
TPCN	Technical Procedure Change Notice
USAF SMC	United States Air Force, Space and Missile Systems Center

## SECTION 11

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