NO. KSC-2005-018-00002

VEHICLE ASSEMBLY BUILDING FIRE

MISHAP INVESTIGATION REPORT

VOLUME I OF V

March 11, 2005

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March XX, 2005

UB-I

TO: AA/Center Director

FROM: Chairperson, Mishap Investigation Board

SUBJECT: VAB Fire, Mishap No. KSC-2005-XXX

In accordance with your request on January 14, 2005, an investigation of the subject Mishap has been completed. The Mishap Investigation Board has established a proximate cause, root causes, contributing factors, and significant observations, and recommends actions to prevent recurrence. The results of this investigation are respectfully transmitted herein.

The investigation was conducted in accordance with NPR 8621.1A, "NASA Procedural Requirements for Mishap Reporting, Investigating, and Recordkeeping", dated February 11, 2004, and KDP–KSC-P-1474, "Mishap Investigation Board". Transmitted herein are Volumes I and II in final form. Volumes III, "Corrective Action Plan", and Volume IV, "Lessons Learned Summary", will be completed by Institutional Safety Division, SA-E. Volume V, "Witness Statements/Testimony", is transmitted to SA under separate cover. This volume consists of witness statements and taped interviews and will be made available to you if you need it for your review and approval of the report.

Feel free to contact me at 867-6164 if I may be of any assistance to you during your review of this report.

Ira Kight

Enclosure

No. KSC-2005-018-00002

VEHICLE ASSEMBLY BUILDING FIRE MISHAP INVESTIGATION REPORT

SECTION II

Signature Page

We, the undersigned as members of the Vehicle Assembly Building Fire Mishap Investigation Board, do hereby certify that the information contained herein is true to the best of our knowledge.

Chairperson:	Ira Kight, UB-J	3/11/05 Date
Voting Members:	Steven Luciano, PH-J1	3/15/05 Date
	Michael B. Stevens, TA-G	3/14/05 Date
	W. Max Farley, TA-D1	3/11/05 Date
	Bryce D. Collins, OP-OS-JP	3/14/05 Date
	William C. Potteiger, PH-O	3/11/05 Date
	Jodi Levesque, UB-C4	3-11-05 Date
Legal Advisor:	Tracy Lee Belford, CC-A	3/14/05 Date
Ex-Officio:	John Brand, SA-F	3/11/05 Date

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SECTION III

List of Members, Advisors, Observers, and Others

NAME	MAIL CODE	BOARD POSITION
Ira Kight	UB-I	Chairperson
Steven Luciano	PH-J1	Voting Member
Michael B. Stevens	TA-G	Voting Member
W. Max Farley	TA-D1	Voting Member
Bryce Collins	OP-OS-JP	Voting Member
William C. Potteiger	PH-O	Voting Member
Jodi Levesque	UB-C4	Voting Member
Leon McGovern	SGS	Consultant
Tracy Lee Belford	CC-A	Legal Advisor
John Brand	SA-F	Ex-Officio

SECTION IV

Executive Summary

On January 13, 2005, at approximately 1355, smoke was noticed on the 4th floor of D Tower in the Vehicle Assembly Building (VAB). Subsequently, a 911 call was made, a fire alarm pull station was activated, and the VAB was evacuated.

The source of the smoke was determined to be a fire on the Low Bay M/N section roof near the Launch Control Center (LCC) Crossover. A subcontractor to Space Gateway Support (SGS), Hamilton Roofing, Inc. (HRI), was performing roof repairs in this area due to extensive wind damage during the 2004 hurricane season.

SGS estimates the cost of the roof damage to be $2,500 or less, making this a Type D mishap. There were no injuries to personnel. Due to the high visibility of the mishap, the KSC Center Director appointed a Mishap Investigation Board. Damage to government property was limited to the roof and a small number of ceiling tiles that were damaged by the fire fighters during the response. At the time of the mishap, there were hazardous commodities in the VAB including Solid Rocket Motors (SRMs) with open grain due to Solid Rocket Booster (SRB) igniter inspections.

The Board agrees with the SGS Fire Services' theory that large amounts of smoke concentrated in the VAB D Tower and moved downward into the cable tunnel. Smoke detector alarms and the corresponding time of the alarms confirmed that smoke began in D Tower and moved downward to the cable tunnel under the transfer aisle between D Tower and A Tower. The wind blew the smoke from underneath the Low Bay M/N section roof surface inside the parapet wall to the 4th floor of D Tower near the LCC turnstile. The wind created a negative pressure in the building which worked as a vacuum to draw the smoke from the fourth floor of D Tower near the LCC turnstile westward toward the vertical electrical chase and then downward to the cable tunnel between D Tower and A Tower.

Dense smoke in the cable tunnel was initially thought to be the result of an electrical fire in the D Tower cable tunnel. Even after the roof fire was located, fire fighters still believed that there was fire somewhere in the cable tunnel and remained focused there throughout the fire response. Only after the roof fire was extinguished did smoke in the cable tunnel begin to subside.

The Board determined the proximate cause of this incident to be torching. HRI was installing a torch applied roof membrane which resulted in the ignition of combustible materials under the membrane near a wooden roof expansion joint.

The torch applied roofing method is a universally accepted safe industry practice when applied to non-combustible surfaces. The combination of an open flame torch and combustible materials presents an increased level of risk even with skilled applicators. The addition of high winds to this combination results in a risk the Board thinks can not be adequately mitigated. An appropriate risk assessment and analysis must be performed on the proposed roofing method to be used on high visibility facilities which represent unique national assets even when using common industry practices for repair and modification.

The Board identified three root causes which contributed to or created the proximate cause and, if eliminated or modified, would have prevented the mishap:

1. Combustible materials in existing roof system
2. Wind speed and direction
3. Inadequate fire watch technique

Two contributing factors were identified which may have contributed to the occurrence but, if eliminated or modified, would not have prevented the occurrence:

1. HRI rushed to dry in and seal the roof on January 13 because heavy rain was predicted for the next day
2. No guidance on torching in windy conditions

A total of 17 significant observations were noted during this investigation, which could lead to another mishap, or increase the severity of a mishap, but were not contributing factors in this mishap. These included: the difficulty in removing power from D Tower in a timely manner which required electricians to enter the VAB and proceed to D Tower 10th floor and E Tower 11th floor to secure power after the evacuation; SGS observed HRI roofers working within a controlled access zone beyond the protective barrier with no safety watch (and took no action); HRI did not consistently perform a fire watch as required each time torching was completed; a functioning disposable lighter was found on the M/N section roof by the fire investigators; and SGS Fire Services has little or no insight into hot work permits issued by United Space Alliance (USA).

A complete list of findings and observations is enclosed in Section VIII.

SECTION V

Method of Investigation, Board Organization, and/or Special Circumstances

The Board convened on Friday, January 14, 2005, to discuss roles and responsibilities and the course of action for the investigation. The Board determined that it required two additional voting members. The Board Chair requested and obtained concurrence for this additional support through the Director of Safety and Mission Assurance.

The Board immediately requested and reviewed written witness statements from the USA Access Control Monitors (ACMs), USA VAB Site Safety representatives, HRI employees, SGS Fire Services personnel, the SGS construction surveillance inspector, and the USA Power Console Operator. The Mishap Board also requested and reviewed daily activity logs from the SGS surveillance construction inspector, the NASA Test Director (NTD), the Chief Test Conductor (CTC), the Orbiter Test Conductor (OTC), USA safety, USA electrical, and SGS electrical.

Discussions with those involved in the incident began with representatives of SGS Fire Services and USA VAB Site Safety. These representatives provided an overview of the activities related to the event. Site visits to the scene occurred on both January 14, 2005 and January 19, 2005. Photos were taken immediately after the mishap and during the investigation to visually document the area and to facilitate the development of possible scenarios to help establish proximate causes, root causes, contributing factors, and significant observations.

The SGS Deputy Fire Chief and several SGS Fire Services personnel who responded to the fire provided an informational walk down of the fire response areas including the mishap site. Informal discussions were held with the USA VAB Site safety representative, the SGS Manager for Construction Services, and the SGS Director of Engineering Services.

The Board Chairperson, the Ex-Officio, and other voting members performed formal interviews with personnel directly involved in the roofing activity that led to the mishap. Those interviewed were HRI personnel who were working on the site, including the owner, foreman, two roofing material applicators/laborers, and the SGS construction surveillance inspector. The interviews commenced Tuesday, January 27, 2005 and were completed on Wednesday, February 2, 2005. During the formal interviews the questions and witness statements were recorded

During the witness interview process, the Board asked questions regarding project safety training, schedule, procedures, processes, reference documents, personnel assignments, and other relevant information. This line of questioning was prompted by data gathered during preliminary

fact-finding, review of written witness statements, photos of the site taken before and after the Board was convened, the Board's observations of the event site, and conversations with personnel involved in events leading up to the mishap.

The Board acquired and listened to Operational Intercommunication System (OIS) voice tapes for channels 232 (CTC command) and radio nets 105 (safety), 110 (pad leader), 116 (fire/rescue), and 216 (fire/rescue). The Board also acquired and listened to the taped 911 fire reporting call.

In the course of the investigation, the Board reviewed pertinent documents provided by National Aeronautics and Space Administration (NASA), USA, SGS and HRI. These documents included contract documentation including HRI's Safety Plan, Occupational Safety and Health Administration (OSHA) regulations, facility and engineering drawings, construction surveillance inspector daily logs, burn permits, electrical switching orders, HRI's daily logs, NPR, KNPR, KDPs and other relevant documents.

The Board systematically and logically analyzed the physical process and operational aspects of the events surrounding the mishap. SGS, Director of Engineering Services, was tasked to provide a preliminary cause-effect analysis. The Board revised and updated this analysis and incorporated final results into Section VII of this report.

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SECTION VI

Narrative Description of Mishap

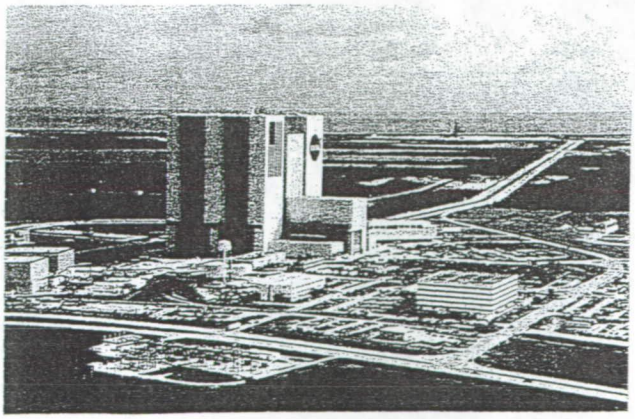
Summary

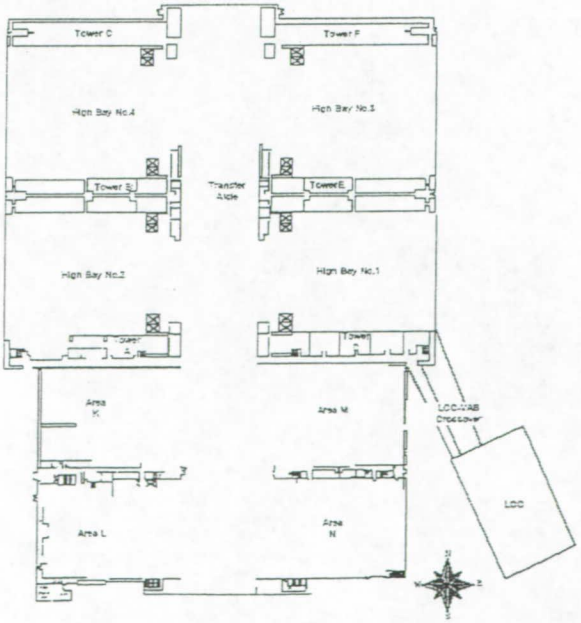
On January 13, 2005, at approximately 1355, smoke was noticed on the 4th floor of D Tower in the VAB. Subsequently, a 911 call was made, a fire alarm pull station was activated, and the VAB was evacuated.

The source of the smoke was determined to be a fire on the Low Bay M/N section roof near the LCC Crossover. HRI, a subcontractor to SGS, was performing roof repairs in this area as a result of extensive wind damage during the 2004 hurricane season. HRI was installing a torch applied roof membrane which resulted in the ignition of combustible materials under the membrane near a wooden roof expansion joint.

Description of Facility

Construction of the VAB at Kennedy Space Center (KSC) was completed in 1965 for assembly of Saturn V launch vehicles for the Apollo Program and was later modified to support vehicle stacking operations for the Space Shuttle Program.





The VAB, one of the largest buildings in the world, covers 8 acres and is 525 feet high, 716 feet long, and 518 feet wide. Enclosing 129,428,000 cubic feet, the building consists of two main areas containing the Low Bays and the High Bays, with a Transfer Aisle running north/south up the middle. High Bays 1 and 3 are integration cells used to stack the Solid Rocket Boosters (SRBs) on Mobile Launcher Platforms (MLPs), mate the External Tank (ET) to the SRBs, and mate the Orbiter to the ET. The completed Shuttle vehicle is checked and then rolled out to the launch pad using a Crawler Transporter (CT). High Bay 2 is used as a Safe Haven in which a stacked Shuttle vehicle, rolled back from the pad, can be stored for hurricane protection in the event both High Bays 1 and 3 are occupied by other vehicles being assembled. High Bay 4 is used for temporary storage of an Orbiter that has to be removed from the Orbiter Processing Facility (OPF) to permit preventative maintenance or modification work in the open bay. Two stand alone ET storage and checkout cells are located in both High Bay 2 and High Bay 4 (two in each bay). Six towers containing office and storage space are located on each side of the High Bays. They are designated Towers A, B, C, D, E, and F. In spite of the enormous amount of office space available, only a few hundred personnel are actually allowed to be housed in the VAB due to the hazard posed by over two million pounds of propellant contained in the SRBs on each Space Shuttle. The Low Bay area is the southern part of the building and serves as a holding and processing area for the SRB Forward Assemblies and sometimes Aft Skirts. The Low Bay also houses office areas designated as the K, L, M, and N sections. USA's main intranet and computer systems for data processing and data communication are located there. A crossover bridge connects the LCC with the VAB, Tower D, providing utility connections and a personnel walkway.

VAB Electrical

The VAB electrical system consists of multiple medium voltage (13.8KV) feeders running from the Utility Annex (UA) to the VAB, specifically to Tower A (2^{nd} floor) and Tower D (4^{th} floor). It is then further distributed to the respective low voltage substations (480/277V) by several other load break switches. All medium voltage switches are manually operated. With exception of two low voltage Unit Substations (USS-816 Low Bay West and USS-800 Tower A 10^{th} floor) all substations are manually operated. The USA Power Console monitors most of the manually operated substations through the Kennedy Complex Control System (KCCS). This provides open/close indications of the substation breakers and in some cases voltage indications. The newer double-ended substations are of the automatic type which, if power is lost from one of the primary feeds, open the respective side main breaker and close the tie breaker, thus restoring power to the side affected. When power is restored the substation returns to the normal configuration automatically. This scheme is controlled by a local Programmable Logic Controller (PLC), and the secondary mains are controllable through KCCS from the Power Console. These substations also provide a myriad of information including status, voltage, current, power, demand, harmonics, etc.

The VAB substations are classified as either industrial or emergency types. An emergency substation is one that is backed-up by the C5 substation generators. These generators are designed and tested to come on line in less than 10 seconds in case of a loss of Florida Power and Light power in order to comply with the National Fire Protection Association (NFPA) Life Safety Code emergency power requirements. Thus, emergency substations feed emergency

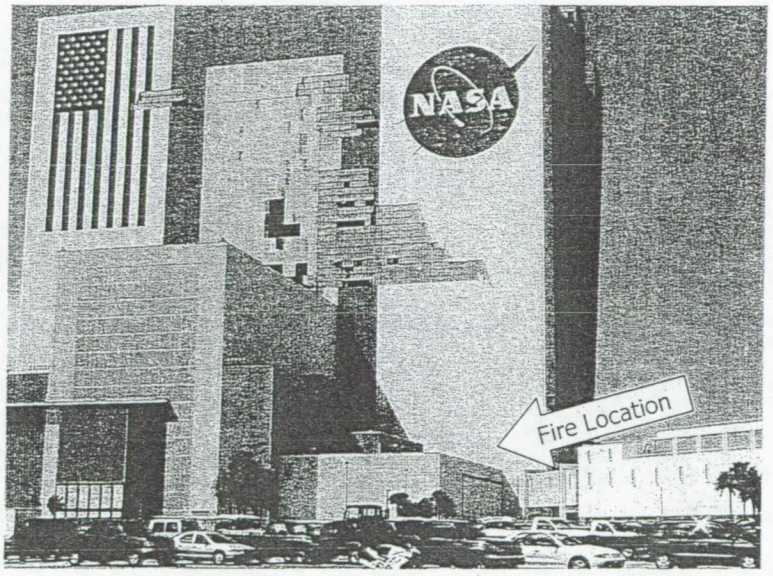
lighting, life safety circuitry and flight hardware/critical systems. There are a total of 12 emergency substations (single feed) in the VAB. Load Break Switch 729 (Tower A, 2nd floor) feeds all emergency substations in the VAB and USS-821B at the LCC, plus any emergency power inside the MLP if it is docked at any of the High Bays.

An industrial substation is one connected to a feeder not backed-up by the C5 substation generators. There are a total of 13 industrial substations (double-ended), not including those used when an MLP is docked in a High Bay. These are fed from several load break switches.

In addition, there is an Uninterruptible Power System (UPS) in the Low Bay West area supplying power to the Shuttle Processing Data Management System (SPDMS)/USA Business Systems and the Photo Analysis Lab. This UPS is composed of 2 redundant 300kW units (UPS-7 & UPS-8) each with its own input feed, one from USS-800 and the other from USS-816. These units are monitored through KCCS.

VAB Fire Mishap

On November 12, 2004, subcontract X05503 was awarded to HRI, through the SGS Subcontracts Administration Office, to provide demolition and removal of the existing bitumen roof system in its entirety. HRI was to supply and install a new 3-ply SBS modified bitumen roof system as listed below:



Task 1: LCC Crossover Roof Area
Task 2: M/N Roof Replacement
Task 3: 16th floor Door Pocket Roof Replacement.

A Notice to Proceed was issued at the pre-work conference held November 12, 2004. This project replaces the roof sections as described above which were damaged during the 2004 hurricane season.

HRI submitted safety plans and received approval from SGS during the period from November 17, 2004 to December 16, 2004. Demolition of the M/N section of the VAB low bay roof began in mid December, 2004.

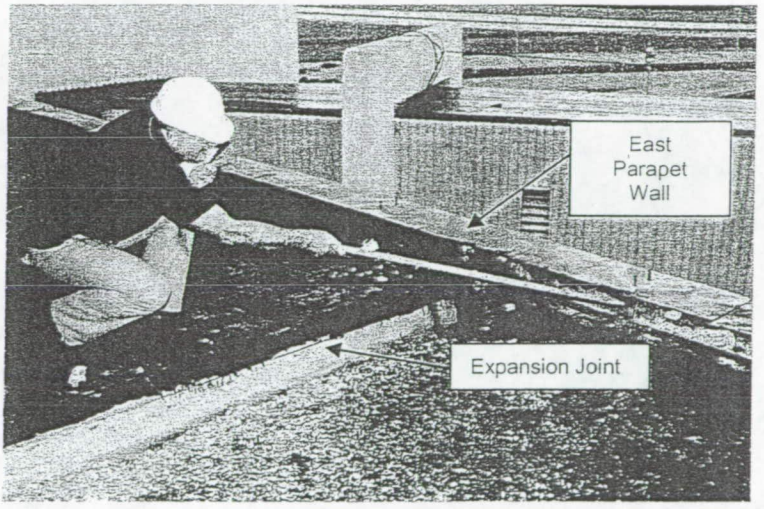
On January 11, 2005, USA VAB Site Safety issued burn permit # VAB 05-019 to allow HRI to perform torching operations necessary to install new bitumen roofing membrane. The permit allowed open flame torching on the roof during the week of January 12, 2005 through January 18, 2005.

On January 12, 2005, HRI cleaned, primed and flashed the combustible wood roof expansion joint that runs east-to-west across the roof area. This provided a protective covering over the expansion joint.

On January 13, 2005, at 0810, a wind warning was issued forecasting steady state winds at 18 knots from 140 degrees.

At 0824, a KCCS outage was opened and servers were all taken off line at 0905. All remote visibility to electrical power was lost at this time.

At approximately 0830, HRI personnel began work on the M/N section of the VAB roof. The work planned for that day included the use of torches in multiple locations. Three HRI employees were present throughout the morning and one of the owners of the company was on site for the early part of the morning. Torching work was done throughout the morning on the east parapet wall and near the combustible wood roof expansion joint that runs east-to-west across the roof area, but not directly on wood roof expansion joint which was protected by two layers of bitumen roofing membrane (installed the previous day).



At 1005, a wind warning was issued forecasting gusts of 35 knots or higher from 140 degrees.
At approximately 1030, HRI personnel made the decision to stop work due to high winds. Shortly thereafter HRI personnel allegedly left the roof for an early lunch.

The Board was unable to determine when HRI personnel left, or the exact time that they returned to the roof. The Board believes that the roofers returned to the roof some time between 1115 and 1130. Once they returned to the roof additional torching was performed, but not in the area where the fire occurred.

At approximately 1330, HRI personnel made the decision to leave the site for the day based on the prediction of continued inclement weather.

At 1355, a USA ACM noticed smoke on the VAB 4th floor of D Tower. The fairly new employee notified the ACM office via radio net 110. A second ACM responded to D Tower and made a 911 call from the phone near the 4th floor turnstiles initiating the fire response. The remaining ACM in the ACM office contacted the USA VAB Site Safety representative, who instructed the ACM to pull the fire alarm. The ACM office representative requested Safety assistance in positively identifying the smoke, thinking it could possibly be dust from sandblasting.

At 1358, the fire crew departed Station 2, heading to the VAB. The Joint Communication Control Center (JCCC), room LCC 1P10, reported to the CTC and Safety Console in LCC Control Room 3 that the fire crew was responding to VAB D Tower due to a 911 call reporting smoke.

At approximately 1400, SGS Fire Services personnel arrived on the scene and established Incident Command. Fire fighters noted smoke in the transfer aisle of the VAB and requested evacuation of the VAB.

At 1401, a USA VAB Site Safety representative arrived in D Tower and, after verifying the presence of smoke, activated the pull station on the 3rd floor in N section, causing the fire alarm bells to ring throughout the VAB and initiating the evacuation.

At 1406, to reinforce the need to evacuate, the Fire Incident Commander instructed the CTC to activate the evacuation warbler.

At 1412, the first smoke detector alarm was received at LCC 1P10, (JCCC), from room 4D10 of D Tower.

At 1425, SGS Fire Services personnel reported visible smoke coming into the transfer aisle from the 3rd and 4th floors of D Tower.

At 1426, a second smoke detector alarm was received at the JCCC, from the D Tower cable tunnel.

At 1432, a third smoke detector alarm was received at the JCCC, from the A Tower cable tunnel.

At 1433, the Fire Incident Commander requested power to be shut off to D Tower.

Fire fighters continued to search for a source of the fire in all areas of D Tower and in adjoining spaces with main emphasis on the cable tunnel. Fire fighters remained convinced there was an electrical fire in the D Tower cable tunnel. Because smoke typically rises from the lowest point, the dense smoke in the tunnel strengthened their theory that the fire source was in the tunnel.

At 1436, firefighters inspected the east Low Bay M/N roof and LCC crossover areas and reported no evidence of fire.

At approximately 1450, USA and SGS electricians arrived at Incident Command and were escorted by fire fighters to the 10th floor of D Tower and the 11th floor of E Tower to secure power.

At 1456, mutual aid was requested from Titusville and Patrick Air Force Base (PAFB) to backfill KSC Fire Stations.

At 1500, USA electricians opened USS-806 secondary main breakers 3B & 9B, and USS-876 secondary main breaker 3 on the 10th floor of D Tower.

At 1506, a fire engine and fire fighting personnel from Titusville arrived at KSC fire station 4 in response to a mutual aid request.

At 1510, KCCS servers were brought back on line.

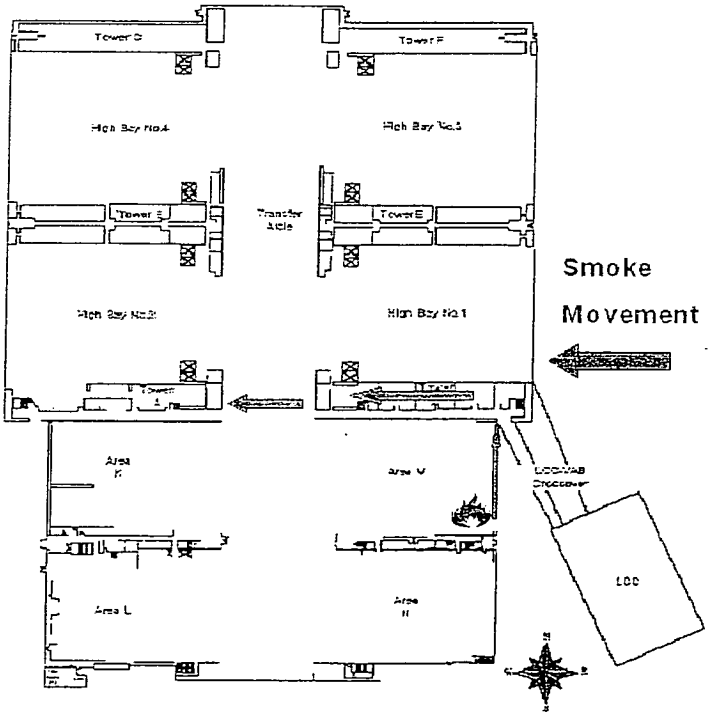
At 1511, fire fighting personnel from PAFB arrived at CCAFS fire station 1 in response to a mutual aid request.

At 1513, USA electricians opened USS-878 secondary main breaker 3 on the 11th floor of E Tower.

Fire fighters reported lights still on in the cable tunnel.

Fire fighters continued to search for the source of smoke and returned to the M/N section of the Low Bay roof.

At approximately 1516, fire fighters found a small section of the roof glowing near the parapet wall. Upon further investigation, the fire fighters confirmed that there was a fire beneath the roofing membrane. Fire fighters began to extinguish the fire on the roof while other fire fighters continued to search for an additional fire source in the cable tunnel area.



At 1538, USA electricians opened USS-816 secondary main breakers 1B & 9B to remove additional power to the M/N section because fire fighters reported that they were receiving shocks while digging on the roof.

At 1545, the Fire Incident Commander requested electricians to return to Incident Command. The Fire Incident Commander was concerned that power was still not completely secured in D Tower and considered removing all power from the VAB.

At 1549, fire fighters reported that an electrical cabinet in the D Tower tunnel was showing hot on the Infrared imaging gun.

At 1600, the Fire Incident Commander requested to CTC that all power to the East side of the VAB be secured.

At 1605, USA power console, in response to prior request to secure remaining power to M/N section, requested permission from the CTC to secure USS-870, breaker 7 in A Tower which would remove emergency power from the Low Bay.

At 1606, the CTC advised the electricians to coordinate with the Fire Incident Commander for removal of emergency power.

At 1613, SGS electricians secured Load Break Switch LBS-729 by opening Vacuum Fault Interrupt VFI-762/V1 at the Utility Annex (UA), removing power from all emergency substations in the VAB and eliminating the need to open USS-870, breaker 7.

At 1615, the fire on the M/N section roof was declared extinguished.

At 1616, the entire East side of the VAB was powered down by SGS electricians at the UA by opening Substation SS701/ACB3 and SS703/ACB3. However, fire fighters continued to report that the lights remained on in the cable tunnel.

At 1619, soon after the fire was declared extinguished on the M/N section roof, the fire fighters re-entered the cable tunnel and reported that the smoke was beginning to dissipate.

At 1623, fire fighters reported no more smoke in cable tunnel.

At 1630, fire fighters reported that M/N section roof operations were completed and that the fire fighters were leaving the roof.

At 1632, fire fighters continued searching for a connection between the roof fire and the dense smoke in the cable tunnel.

At 1637, OV-104 (Atlantis) was powered down as a precaution against possible power anomalies related to electrical switching activities.

At 1648, OV-103 (Discovery) was powered down as a precaution against possible power anomalies related to electrical switching activities.

At 1651, the Fire Incident Commander declared that no further power needed to be removed from the VAB.

At 1652 and 1659, respectively, mutual aid responders from Titusville and PAFB Fire departments were released.

At 1703, a thermal scan of the M/N section roof and the ceiling below by the fire fighters revealed no more evidence of hot spots in these areas.

At 1806, the Fire Incident Commander declared the VAB as fire safe and released the VAB to SGS security.

At 1816, the Fire Incident Commander, the NASA Authority Having Jurisdiction (AHJ), and the Chief of Fire Prevention made an initial assessment of the fire scene.

At 1826, the USA VAB Site Safety representative, the NASA Shuttle Safety supervisor, the SGS Director of Engineering Services, and the HRI Co-Owner were escorted by the Chief of Fire Prevention to the M/N section roof for evaluation of the fire scene to determine how to temporarily secure the roof.

At 1840, HRI was allowed to make temporary repairs to prevent water intrusion from anticipated rain storms that were approaching the area.

At 1930, the NASA Mishap Investigation Board chair was selected by KSC Center Director.

At 2000, a meeting was held to discuss restoration of power, return to operations, securing all areas penetrated by fire fighters, and extent of the impoundment area.

At 2107, USA/SGS electricians returned to the VAB to begin power restoration.

At 2240, power-up of OV-103 (Discovery) was initiated.

At 2247, all power was restored to the VAB.

At 2258, the VAB was reopened for limited work access.

At 2304, power-up of OV-103 (Discovery) was completed. Note: OV-104 (Atlantis) was not powered-up until the next morning due to a lack of manpower on 3rd shift.

At 2330, the VAB was reopened for normal work.

On Friday, January 14, 2005, Mr. James Kennedy, KSC Center Director, appointed a Mishap Investigation Board to investigate the incident, determine the root cause, and make recommendations to prevent recurrence of this mishap.

The Mishap Investigation Board convened at the site of the incident at 0930 on Friday, January 14, 2005.

Related Events

The power-down of OV-103 (Discovery) and OV-104 (Atlantis) had no apparent impact on the overall Shuttle processing schedule for return to flight.

SECTION VII

Data Analysis

Introduction

Data was analyzed to determine the proximate and root causes and contributors to the mishap. The analysis was approached systematically through utilization of a timeline and a cause-effect diagram. The primary sources of data were fire fighters, HRI personnel, personal observations by the Board members, HRI's Safety Plan, contract documentation, and OSHA regulations. Additional sources included facility and engineering drawings, construction surveillance inspector daily logs, burn permits, electrical switching orders and HRI daily logs.

Fire Analysis and Theory

No direct torching of exposed combustibles was performed on the day of the fire, January 13, 2005. A new membrane had been torched to the wood expansion joint a day earlier, January 12, 2005. However, torching was performed in the corner where the expansion joint butts against the parapet wall to seal the flashing to the parapet. An existing cover had been attached to the parapet wall up to the expansion joint prior to the fire. The parapet cover was removed by the fire fighters while extinguishing the fire. The parapet cover may have served as a conduit for the transfer of flame and heat to combustible materials located in the wood expansion joint and the non-contracted roof section on the opposite side of the expansion joint.

The Board agrees with the SGS Fire Services' theory that large amounts of smoke concentrated in the VAB D Tower and moved downward into the cable tunnel. Smoke detector alarms and the corresponding time of the alarms confirmed that smoke began in D Tower and moved downward to the cable tunnel under the transfer aisle between D Tower and A Tower. The wind blew the smoke from underneath the Low Bay M/N section roof surface inside the parapet wall to the 4th floor of D Tower near the LCC turnstile. The wind created a negative pressure in the building which worked as a vacuum to draw the smoke from the fourth floor of D Tower near the LCC turnstile westward toward the vertical electrical chase and then downward to the cable tunnel between D Tower and A Tower.

Detailed Timeline

A detailed timeline was constructed in order to identify events related to the mishap. It begins with award of SGS subcontract for various roof repairs as the result of hurricane damage, included fire response events, and ends with the convening of the Mishap Investigation Board.

Date	Time	Event
11/12/04		SGS awarded roof repair contract to Hamilton Roofing, Inc (HRI)
11/12/04		Notice to Proceed issued / Pre-work conference held
11/17/04		HRI Safety Plan submitted
11/23/04		SGS approved HRI Safety Plan
12/12/04		HRI Accident Plan and other safety plans submitted
12/16/04		SGS approved all HRI-submitted plans
1/11/05		USA VAB Site Safety issued burn permit VAB 05-019 for hot work during the period January 12 – January 18, 2005
1/12/05		HRI cleaned, primed, and flashed wood expansion joint
1/13/05	0810	Wind warning issued forecasting steady state 18 knots at 140 degrees
1/13/05	0824	Outage 546517 opened for loss of KCCS due to server relocation
1/13/05	0830	HRI torch work on M/N section roof began for day (flashing parapet)
1/13/05	1005	Wind warning issued for gusts 35 knots or higher at 140 degrees
1/13/05	1030*	Decision to stop work due to high winds; HRI personnel left the roof
1/13/05	1130*	HRI returned to the roof (torching membrane over anchor plates away from parapet and expansion joint)
1/13/05	1330*	HRI left site for the day
1/13/05	1355 - 1357	While conducting routine shift walkdown of D, E, and F Towers, a VAB ACM noticed smoke on the 4th Floor of D Tower. He contacted the ACM office on radio net 110. A second ACM quickly joined the first, in D Tower and made a 911 call from the phone near the 4th Floor turnstiles. The remaining VAB ACM in the ACM office contacted USA VAB Site Safety and reported smoke on the 4th Floor of D Tower. USA VAB Site Safety instructed him to pull fire alarm, but he requested Safety to assist in positively identifying smoke since he thought it could be dust from sandblasting.
1/13/05	1358	KSC fire crew departed fire station 2 for VAB JCCC, LCC room 1P10, reported to CTC and Safety Console in LCC Control Room 3 that Fire Services was responding to VAB, D Tower, due to a 911 call reporting smoke.
1/13/05	1400*	Fire crew on site, smelled smoke in transfer aisle and requested VAB evacuation

1/13/05	1401	USA VAB Site Safety arrived in D Tower, verified smoke, and pulled fire alarm on 3rd Floor, N Section of Low Bay, activating fire bells throughout VAB
1/13/05	1406	Fire Incident Commander instructed CTC to activate warbler for evacuation
1/13/05	1412	JCCC, LCC room 1P10, reported smoke detector activation in room 4D10
1/13/05	1425	SGS Fire Services reported visible smoke coming into the Transfer Aisle from the 3rd and 4th floors of D Tower
1/13/05	1426	JCCC, LCC room 1P10, reported smoke detector activation in D Tower Cable Tunnel
1/13/05	1432	JCCC, LCC room 1P10, reported smoke detector activation in A Tower Cable Tunnel
1/13/05	1433	Fire Incident Commander requested electricians to shut off power to D Tower.
1/13/05		Fire fighters continued to search for the source of the fire in all areas of D Tower and in adjoining spaces with main emphasis on the cable tunnel.
1/13/05	1436	Firefighters inspected east Low Bay roof and LCC Crossover and reported no problems
1/13/05	1450*	USA/SGS electricians arrived at Incident Command and were escorted by fire fighters to the 10th floor of D Tower and the 11th floor of E Tower to secure power.
1/13/05	1456	Mutual aid was requested from Titusville and PAFB
1/13/05	1500	USA electrician opened USS-806 secondary main breakers 3B and 9B and USS-876 secondary main breaker 3 on the 10th floor of D Tower.
1/13/05	1506	Fire engine and fire fighting personnel from Titusville arrived at KSC fire station 4
1/13/05	1510	KCCS servers were brought back on line
1/13/05	1511	Fire fighting personnel from PAFB arrived at CCAFS fire station 1
1/13/05	1513	USA electrician opened USS-878 secondary main breaker 3 on the 11th floor of E Tower
1/13/05		Fire fighters reported lights still on in the cable tunnel. Fire fighters continued to search for the source of smoke and returned to the M/N section of the Low Bay roof.
1/13/05	1516*	Fire discovered on roof M/N section and extinguishment begun.
1/13/05	1538	USA electrician opened USS-816 secondary main breaker 1B and 9B because fire fighters reported that they were experiencing shocks while digging on the roof.
1/13/05	1545	The Fire Incident Commander requested that electricians return to Incident Command. The Fire Incident Commander was concerned that power was still not completely secured in D Tower and considered removing all power from the VAB.

1/13/05	1549	Fire fighters reported that the infrared imager showed a hot cabinet in tunnel.
1/13/05	1600	Fire Incident Commander requested that all power to the east side of the VAB be secured
1/13/05	1605	USA Power Console requested permission from CTC to secure USS-870/Breaker #7 in A Tower to remove emergency power from the Low Bay.
1/13/05	1606	CTC advised the electricians to coordinate with the Fire Incident Commander for removal of emergency power.
1/13/05	1613	SGS electricians secured Load Break Switch LBS-729 by opening Vacuum Fault Interrupt VFI-762/V1 at the Utility Annex (UA), removing power from all emergency substations in the VAB and eliminating the need to open USS-870, breaker 7.
1/13/05	1615	Fire on M/N section roof declared extinguished.
1/13/05	1616	The entire East side of the VAB was powered down by SGS electricians at the UA by opening substation SS701/ACB3 and SS703/ACB3. However, fire fighters continued to report that the lights remained on in the cable tunnel.
1/13/05	1619	Fire fighters re-entered the cable tunnel and reported that the smoke was beginning to dissipate.
1/13/05	1623	Fire fighters reported no more smoke in cable tunnel.
1/13/05	1630	Fire fighters reported that M/N section roof operations were completed and that the fire fighters were leaving the roof.
1/13/05	1632	Fire fighters continued searching for a connection between the roof fire and the dense smoke in the cable tunnel.
1/13/05	1637	OV-104, Atlantis, was powered down as a precaution against possible power anomalies related to electrical switching activities.
1/13/05	1648	OV-103, Discovery, was powered down as a precaution against possible power anomalies related to electrical switching activities.
1/13/05	1651	Fire Incident Commander declared that no further power needed to be removed from the VAB.
1/13/05	1652	Mutual aid support from Titusville was released
1/13/05	1659	Mutual aid support from PAFB was released
1/13/05	1703	Thermal scan of the M/N section roof and the ceiling below by the fire fighters revealed no more evidence of hot spots in these areas
1/13/05	1806	The Fire Incident Commander declared the VAB as fire safe and released the VAB to SGS security.
1/13/05	1816	The Fire Incident Commander, the NASA Authority Having Jurisdiction (AHJ), and the SGS Chief of Fire Prevention made an initial assessment of the fire scene.
1/13/05	1826	The USA VAB Site Safety representative, the NASA Shuttle Safety supervisor, the SGS Director of Engineering Services, and the HRI Co-Owner were escorted to the M/N section roof by the SGS Chief of Fire Prevention for evaluation of the fire scene to determine how to temporarily secure the roof.

1/13/05	1840	HRI allowed in to make temporary repair to prevent water intrusion from anticipated rain storms approaching the area
1/13/05	1930	NASA Investigation Board Chair selected
1/13/05	2000	Meeting held to discuss power restoration, return to operation, securing all areas penetrated by fire fighters, and extent of the impoundment area.
1/13/05	2107	USA/SGS electricians re-entered VAB to restore power
1/13/05	2240	Power up of OV-103, Discovery, was initiated
1/13/05	2247	All power restored in VAB
1/13/05	2258	VAB reopened for limited work access
1/13/05	2304	Power up of OV-103, Discovery, was completed.
1/13/05	2330	VAB re-opened for normal work
1/14/05		NASA Investigation Board activated

* Exact times could not be verified but are believed to be accurate.

Cause - Effect Analysis

In an effort to identify the proximate and root causes of this mishap, a cause – effect fishbone diagram was constructed (*see Figure 1: Cause – Effect Diagram*). This diagram was used to ensure all potential cause categories were considered. The categories identified include:

Design
Safety Planning
Human Factors
Existing Conditions
Weather
Worker Training

A general discussion of each category is provided below.

Cause Category: Design

Torch-applied roofing was specified in design: There are four roofing applications typically considered for roofing projects by KSC. The applications are

1. Hot Mopped Asphalt applied SBS Membrane
2. Torch applied SBS Membrane
3. Cold-Adhered Asphalt Emulsion applied SBS Membrane
4. Liquid-applied Elastomeric coating (High pitched roofs (typically metal))

The SGS roof specification for each project considers the following design factors:

1. First Cost and life-cycle (long-term) cost
2. Energy Conservation opportunities
3. Value and vulnerability of building components
4. Required service life
5. Climate
6. Maintenance
7. Availability of materials and competent applicators
8. Local practices
9. Building code fire resistance and wind uplift requirements
10. Environmental factors

The basic roof design of the low-slope roof system generally has three components:

1. Structural deck
2. Thermal insulation
3. Membrane

A hot mopped asphalt application has the following advantages:

1. Excellent resistance to water penetration and extremely low water absorptive qualities.
2. Durability under prolong exposure to weather.
3. Good internal cohesion and adhesion.

4. Thermo-plasticity
5. Produces superior lap seal.
6. Safer than torching.

Hot Mopping has some disadvantages, notably:

1. The need for ancillary operations- preheating in a kettle, transport of hot asphalt to point.
2. Greater slippage hazard attributable to use of softer, more fluid bitumen, producing thicker layers.

A torch applied application has the following advantages:

1. Excellent resistance to water penetration and extremely low water absorptive qualities.
2. Durability under prolong exposure to weather.
3. Thermo-plasticity
4. Generally faster than mopping
5. Less slippage hazard than mopping
6. No ancillary operations as required for mopping.

Torching has some disadvantages, notably:

1. Unless it is performed fast, it will produce poor adhesion.
2. Greater chances of igniting combustibles.
3. Produces poor lap seal due to the applicator using too little or too much heat.

Cold Asphalt Emulsion and Liquid-applied Elastomeric coating are referred to as cold processes and are generally less expensive and used for refurbishments and re-roofing. This technique is normally restricted to facility maintenance and repair programs of damaged built-up systems when it is uneconomical to bring in heavy equipment, hot tar kettles, asphalt dispensers, etc.

Based on the design factors listed above, the hot mopped solution would typically be selected for the M/N section roof. However, due to roof height, a hot tar kettle would be required on the roof. SGS determined that this would have represented an unacceptable fire risk. Selection of the cold adhered or liquid coating would not provide adequate assurance of a reliable weather seal, and given the criticality of the facility, would not be acceptable.

SGS selected the torch-applied method as it is a universally accepted safe application. In this case the system was typically being applied to non-combustible surfaces. The underlying roof layer was a 2" lightweight concrete surface and side edging (except for existing expansion joint) is comprised of concrete or metal surfaces. Industry has no restrictions on the application of torch-applied materials on wood surfaces; however does recommend the use of a protective barrier. SGS determined that the torch-applied system represented the best acceptable risk.

The open flame torch, by providing a flame source on the roof to ignite combustibles, was determined to be the proximate cause and if eliminated would have prevented the mishap.

Limited consideration for work near combustibles was provided in the design: There are no typical restrictions to the use of torch-applied roofing over wood; however, the introduction of direct flame to combustibles clearly represents an increase in risk.

> Note: If limited areas of combustibles are present, designs shall use a non-combustible covering or a first layer of cold-adhered roofing in those limited locations to the extent feasible without compromising the integrity of the weatherproofing system and its warranty.

No consideration for wind speed was included in specifications: The design specifications contained no guidance for torching operations in windy conditions. Additionally, there is no known industry standard concerning wind. However, the wind speed and direction clearly contributed to the mishap.

The lack of clear guidance or direction concerning wind speed pertaining to torching may have contributed to the mishap.

Cause Category: Safety Planning

Fire Watch: A burn permit (VAB 05-019) was in place that specified there must be an on-site fire extinguisher and a fire watch during and after use of flame. The work crew visually checked the work site prior to leaving; however it is not certain when torching stopped and whether the fire watch was performed as required. Later, the area was again visually inspected by fire fighters, in response to fire alarm activation, but no evidence of fire was discovered. If the combustible area is fully visible, the fire watch, as specified in the permit, is a good requirement. However, if the construction process conceals the combustible material, as in this case, the visual inspection will not reveal all potential areas of combustible material ignition. The inadequate fire watch technique did not directly contribute to the combustible materials ignition, but did directly cause an increase in the consequences of the ignition via the extended duration of smoldering and smoke generation prior to discovery.

The inadequate fire watch technique is considered to be a root cause.

Cause Category: Human Factors

Excessive work hours by crew: No evidence of work crew fatigue were identified or reported. Mishap occurred early in the shift precluding impact from extended work hours.

Pressure to seal the opened roof area was a driver due to rain and winds reported as approaching: Sealing is required to ensure protection of assets within the facility. The sealing could have been affected by either completion of the work or placement of temporary mitigation (e.g., tarps). Due to elevation of roof and historically high wind speeds caused by the elevation and channeling of winds around the VAB, tarps were not considered a reliable patch and completion of work was highly desirable.

The pressure to dry in and seal the roof may have contributed to the mishap.

Cause Category: Existing Conditions

Combustibles used in existing roof system: This is a reasonably expected condition on most existing roofs. However, the introduction of direct flame to combustibles clearly represented an increase in risk.

The presence of combustibles is considered to be a root cause.

Parapet system prevented visual inspection: The existing parapet system provided a pathway for a wind driven oxygen source adjacent to the installed roofing and provided a visual obscured pathway for distribution of the combustion products into the VAB interior. It is not known whether the parapet contributed to the fire or the transfer of the smoke into the VAB.

The parapet system is not considered to be a contributing factor.

Cause Category: Weather

Wind cooling of surfaces required longer flame exposure to roof: The cooling effect of the high winds required a longer application of the heat source. The extended exposure of the roofing materials to the heat source dramatically increased the potential for ignition. This is considered to be a direct contributor to the mishap.

Wind changed flame path: The high winds redirected the nominal flame path and allowed flame impingement on areas not visible. The errant application of flame to combustible roofing materials dramatically increased the risk of an unseen ignition point. This is considered to be a direct contributor to the mishap.

Wind direction: The high winds and parallel direction forced a wind driven oxygen source inside the roofing system or parapet system. The enriched oxygen environment helped to fan the fire and transfer smoke into the VAB. This is considered to be a direct contributor to the mishap.

Wind speed and direction is considered to be a root cause.

Cause Category: Worker Training

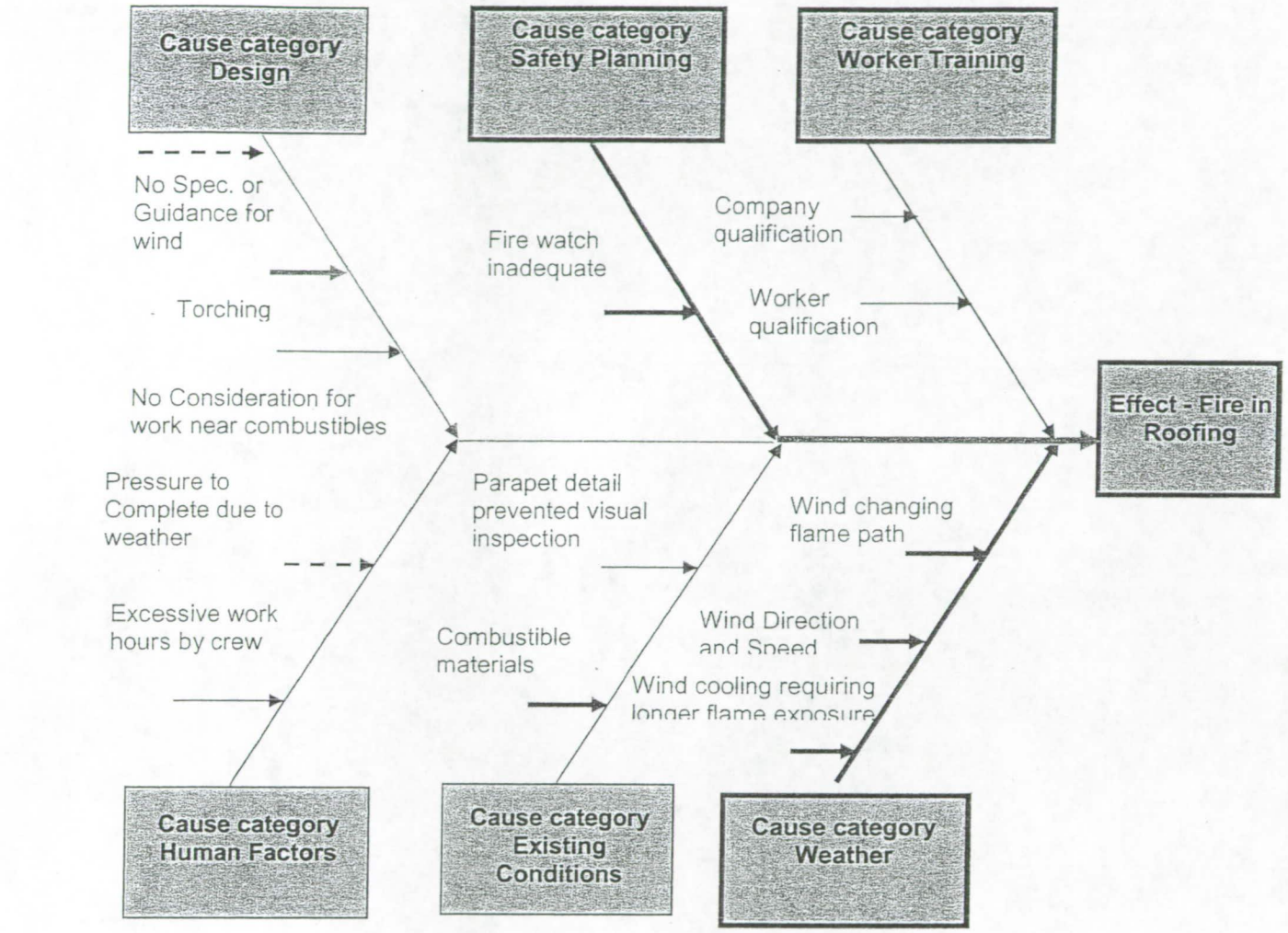
Company Qualifications: The contract specifications required certification of the company and workers. Further, the Manufacturer's warranty required the company and workers be trained and certified by them for application of their roofing materials as a condition to providing the warranty. Soprema ® has certified that HRI has been certified to apply its products for over 10 years.

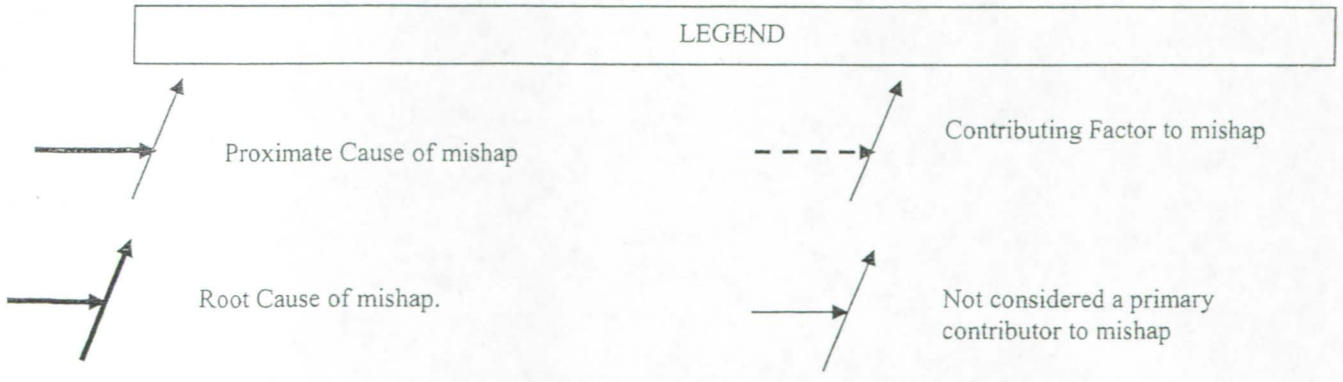
Training and qualification of the company is not considered to be a contributing factor.

Worker Qualifications: As stated above, worker training and qualification is required as well as company certification for torch applied systems. In addition to manufacturer certification in torch applied roofing, HRI workers are stated by HRI to have had safety awareness training that covers all aspects of roofing, On the Job Training in roofing and hold weekly project and work safety "toolbox" meetings.

Training and qualification of the worker is not considered to be a contributing factor.

Figure 1: Cause Effect Diagram





Documentation Review

A review of HRI training certifications revealed that all HRI personnel installing the VAB roof system were fully trained and certified to install torch applied roofing systems by the manufacturer, Soprema.

A review of contract documentation including design specification, installation drawings, and manufacturer's specifications revealed the following inconsistencies:

The specification required a fire watch for 60 minutes following the termination of torching operations. The burn permit required a 30 minute fire watch. HRI's safety plan did not address the fire watch.

The specifications called for two water and two CO2 fire extinguishers for use during the fire watch. The burn permit called for "Appropriate Type Fire Extinguishers on-site at all times."

A review of contract documentation including design specification, installation drawings, and manufacturer's specifications revealed the following inadequacies:

The solicitation required HRI to "...establish wind restrictions..." for operations. These wind restrictions were primarily addressing safety of personnel. There is no requirement for addressing "wind speed" as it relates to or affects torching operations. The effect of wind speed on torching was not addressed in the special conditions or HRI's safety plan.

Interim Restrictions

The Board Chairman, with concurrence of the NASA AHJ, immediately required interim restrictions for torch applied modified bitumen roofing to be implemented as a condition of HRI resuming work at the VAB and other sites. Improper use of roofing materials and application equipment can result in severe burns, and/or other physical injury, as well as damage to property. SGS embraced these recommendations and implemented them to all SGS work. KSC Director of Safety and Mission Assurance has required the use of these interim restrictions in all areas of KSC until the VAB Fire Mishap Investigation is completed and the final KSC policy is established and implemented.

The interim restrictions limit torching and require all torching to cease when winds exceed 15 mph. Additionally, no torching is allowed within 3 feet of combustibles or areas where the presence of combustibles is not known. A glue and stick application or equivalent is to be used in these locations.

The Board recommends the use of Infrared (IR) heat detection gun to assist in the fire watch.

Additional Research Regarding Torch Applied Roofing Products

In an effort to further document standard industry practices, the Board researched via the internet and found the following information from GAF, a major roofing manufacturer:

Installation of torch-applied products creates the **risk of fire**, including smoldering fires. Torch-applied products must be applied only by professional roofing applicators trained in proper torch application and safety procedures. Roofing applicators must follow current roofing safety requirements, procedures and specifications. Procedures and equipment that will be used must comply with all applicable code requirements. Knowledge of the building construction and HVAC and other roof systems must be obtained prior to installation of torch-applied products. All potentially combustible and flammable aspects of the buildings use and design that increase the risk of fire must be identified. A base sheet must be used between the roofing membrane and any combustible materials such as wood. **Never apply flame directly to combustible materials or allow the flame to enter into hidden or protected areas that may contain combustible materials.** A supervisor trained in torch safety must conduct external and internal fire watches during application and after the torches are shut down. The watches shall never be less than one hour and may need to be longer. **Infrared scanning equipment must be used in the fire watch.** One twenty lb Class ABC fire extinguisher must be kept within 10 feet of every torch operator. The above list is not a complete set of necessary safety requirements, procedures, and specifications. Train all personnel in recommended application techniques. Train all personnel in fire prevention and extinguishing methods. Take precautions when working around combustible materials, such as gas lines for HVAC units, and in the presence of solvent-based products. Use caution to prevent burns and train personnel in first aid procedures. Comply with all applicable fire regulations regarding the storage and use of propane.

URL: http://www.gaf.com/General/SearchSite.asp?Silo=CONT&App=&WS=GAF#

Type "torch safety" in the search window

Click on Search

Click on the link What safety precautions are recommended? Video

Click on the Safety Warning tab

SECTION VIII

Findings, Root Causes, Observations, and Recommendations

What Happened: Mishap

VAB Low Bay M/N section roof was damaged as the result of a fire.

Why it Happened: Proximate cause

P1.0 Finding:
An **open flame torch** was used on roofing operations at the combustible expansion joint.

P1.1 Recommendation:
Eliminate the use of open flame torches when combustibles are present or when the presence of combustibles is unknown. On roofs that have combustibles present or where the presence of combustibles is unknown, use a peel and stick, hot mop, or other approved roofing system that does not involve open flame application method (e.g. flameless torch). A risk analysis shall be performed when open flame torching near combustibles can not be avoided. The benefiting Program shall concur with the risk analysis.

What Contributed: Root causes

R1.0 Finding:
Combustibles were located in and near the expansion joint of the VAB M/N roof section where torching was being performed.

(NOTE: The expansion joint consists of 2 wooden beams with an air gap between them. The torching operation ignited combustibles in or near the expansion joint which smoldered for a considerable time before ignition. Combustibles were also located in the non contracted portion of the roof on the opposite side of the expansion joint.)

R1.1 Recommendation:
Eliminate the use of combustible materials for all new roof construction. When not feasible, a risk analysis shall be performed prior to specifying the use of combustible materials. The benefiting Program shall concur with the risk analysis.

R1.2 Recommendation:
Repairs to existing roofs that have combustibles present shall designate removal of all combustibles. If removal is not feasible or the presence of combustibles is unknown, use

a peel and stick, hot mop, or other approved non torch applied roofing system. A risk analysis shall be performed when open flame torching near combustibles can not be avoided. The benefiting Program shall concur with the risk analysis.

R 2.0 Finding:
Wind speed and direction contributed greatly to the ignition of the combustibles at the expansion joint in three different ways:
Torch Longer – The high winds cooled the material faster causing the torch operator to heat the area and material longer and hotter, contributing to the ignition of the combustibles.
Flame spread – The high wind spreads the flame, giving the torch operator less control of the flame direction, heating more of the surrounding area.
Direction- The direction of high wind parallel with the parapet wall created a venturi effect in the parapet wall and provided increased oxygen to the fire. The high winds fanned the smoldering fire causing ignition of the combustibles under the bitumen roof near the expansion joint.

(NOTE: Wind warning was issued at 8:10 a. m. forecasting 18 knot steady state winds at 140 degrees (southeast). At 10:05 wind warning was issued for gusts 35 knots or higher at 140 degrees. HRI noted conditions on the roof were too windy to work at 1:30 p. m.)

R2.1 Recommendation:
Torching operations shall be restricted during windy conditions. A NASA policy shall be developed to identify maximum allowable conditions. Contract specifications shall be updated to reflect new policy. Policy shall specify use of an anemometer (wind meter) at the roof location to measure wind speed at the specific job site.

R2.2 Recommendation:
Contract specification shall require all contractors to submit a Safety Plan to include procedures and restrictions associated with combustibles and high winds.

R3.0 Finding:
A visual **fire watch was inadequate** to detect smoldering combustibles underneath the roofing materials.

R3.1 Recommendation:
The use of an IR Infrared Thermometer Gun shall be incorporated into a fire watch where materials are not completely visible. Personnel shall be trained in the use of an IR gun. Readings shall be taken at completion of the torching operations, and an additional reading one hour after torching operations have ceased to ensure cooling is taking place. Personnel shall not leave roof till fire watch is complete.

What May Have Contributed: Contributing factors

C1.0 Finding:
HRI **rushed to dry in and seal** the roof prior to leaving the job site for the day to prevent water intrusion due to the prediction of heavy rain the next day.

C1.1 Recommendation:
Contractors shall not compromise safety and health principles and practices. Pre-work conferences shall reinforce NASA commitment to safety.

C2.0 Finding:
There was **no guidance** in the solicitation and resulting contract **concerning torching in windy conditions.**

C2.1 Recommendation:
See recommendation R2.1.

Significant Observations:

O1.0 Observation:
There was difficulty in removing electrical power from the VAB D Tower in a timely manner.

(NOTE: The Fire Incident Commander requested the removal of electrical power to D Tower when it was thought that the fire was located in the cable tunnel and could be electrical in nature. Electricians had to be sent to the 10th floor of D Tower, 11th floor of E Tower, and to the west side of the Low Bay to secure various electrical substations in an attempt to secure all power to D Tower. Numerous attempts to remove power from D Tower resulted in approximately 3 hours to eventually remove power.)

O1.1 Recommendation:
In an emergency, consideration shall be given to the removal of all VAB electrical power from the Utility Annex. USA Electrical and SGS Electrical shall develop power removal procedures for various emergency situations in the VAB and other facilities with complex power systems. The developed procedures shall be coordinated with SGS Fire Services personnel.

O1.2 Recommendation:
As VAB substations are replaced, upgrade to remotely controlled substations to avoid manual switching.

O2.0 Observation:
HRI roofers were observed by the SGS inspector working within a controlled access zone beyond a protective barrier along the M/N roof parapet without a safety monitor.

O2.1 Recommendation:
HRI shall be formally notified by the SGS subcontract administrator of the OSHA violation and requested to provide a corrective action plan to assure HRI personnel comply with OSHA fall protection requirements. Reference approved Subcontractor safety plan and OSHA CFR 1926.500-503 (OSHA requires a competent person be designated by the employer to monitor the safety of other employees while working inside a controlled access zone within 6 feet of the leading edge of a low-slope roof that is 6 feet or more above a lower level if workers are not wearing fall protection).

O3.0 Observation:
The SGS construction surveillance inspector noted in his daily log that a safety monitor was not posted for protection of HRI roofers working within 6 feet of leading edge of roof and no corrective action was initiated by the inspector, his lead, or their supervisor.

O3.1 Recommendation:
The SGS construction surveillance inspector shall immediately notify subcontractors on site of safety violations and stop work when appropriate.

O3.2 Recommendation:
SGS shall follow internal procedures to assure leads and supervisors follow up with corrective action concerning daily log entries. ENG-P-0012, Construction Management Processes, shall be updated to reflect Leads' and Supervisors' responsibility to review daily logs and initiate appropriate action as required.

O4.0 Observation:
HRI did not perform a 60 minute fire watch after conclusion of torching operation per contract.

(NOTE: Because the specified fire watch technique was inadequate (see finding R3.0), this finding is not considered a contributing factor.)

O4.1 Recommendation:
Contractors shall be formally notified by the appropriate contract administrator of any Fire Watch violation and requested to provide a corrective action plan to assure that contractor personnel comply with Fire Watch requirements. The Fire Watch requirements shall be specifically addressed in pre-work conferences.

O5.0 Observation:
A functioning disposable lighter was found on the M/N roof by the fire investigators after the fire was extinguished.

(NOTE: The lighter was located on a section of the roof on which HRI had recently completed work. While there is no evidence that this in any way contributed to the cause of the fire, the presence of a lighter in the VAB is a direct violation of posted signage and area access safety training in accordance with NSS 1740.12, Safety Standard for Explosives, Propellants, and Pyrotechnics.)

O5.1 Recommendation:
Reinforce the compliance with area restrictions concerning possession of lighters within certain KSC facilities. For all construction contractors provide reinforcement during pre-work conferences.

O6.0 Observation:
Hot Work Permits are issued by USA Safety per Operating Procedure USA002872, Welding and Burn Permits, in Shuttle processing facilities with SGS Fire Services having little or no insight.

O6.1 Recommendation:
Provide copies of USA Safety approved Hot Work Permits to SGS Fire Services at time of issue. Both the SGS Fire Services Prevention Department as well as JCCC (Fire Dispatcher in LCC 1P10) shall receive copies.

O6.2 Recommendation:
USA Safety, or permit issuing authority, shall inspect all hot work sites daily for compliance with permit.

O7.0 Observation:
Operating Procedure USA002872, Welding and Burn Permits, does not provide complete instruction for USA Site Safety representative, SGS Fire Services, or contractors to provide fire watches for torching.

(NOTE: Operating Procedure only covers fire watch requirements for welding.)

O7.1 Recommendation:
Update Operating Procedure USA002872, Welding and Burn Permits, to include clear instructions for fire watch pertaining to all hot work including torching.

O8.0 Observation:
HRI did not leave the work premises in a clean, neat, and workman like condition as required by contract.

(NOTE: While there were no indications that the condition impeded the responders' ability to locate and extinguish the fire, roofing materials and supplies were relocated and stored in a more orderly fashion after the fire was extinguished later the evening of the mishap.)

O8.1 Recommendation:
HRI shall be formally notified by the SGS subcontract administrator of the job site condition and requested to provide a corrective action plan to assure that subcontractor personnel comply with contract requirements.

O8.2 Recommendation:
Construction surveillance inspectors shall be more proactive in assuring that subcontractors leave the work premises in a clean, neat, and workman like condition at the end of each workday.

O9.0 Observation:
The ET/SRB Operations Center was not aware of the HRI torching operation on the Low Bay M/N section roof.

(NOTE: The ET/SRB Operations Center, located on the first floor of Tower A, is responsible for all integration within the VAB. The Board noted that integration of major VAB facility work with Shuttle processing activity is generally effective; however, smaller facility modification projects, especially subcontractor work, lack visibility and integration. Historically by USA policy, the single focal point for all work in a Shuttle processing facility has always been the facility operations group (i.e. Operations Desk, Pad Leader, etc.).)

O9.1 Recommendation:
The ET/SRB Operations Center in the VAB shall be notified of all work prior to starting and upon completion on a daily basis. In addition to notification of daily operations, all times for hot work shall be specifically identified. Contract provisions shall be added to ensure daily notifications. Pre-work conferences shall reinforce this requirement.

O10.0 Observation:
The SGS construction surveillance inspector did not enforce contract specifications pertaining to the proper number and type of fire extinguishers.

O10.1 Recommendation:
Contract specifications shall be enforced and/or revised.

O11.0 Observation:
The KCCS was offline due to a planned outage which did not allow visibility to the status of electrical power in the VAB.

O11.1 Recommendation:
None. No critical operations were identified requiring KCCS to be online.

O12.0 Observation:
HRI did not submit and SGS did not request a detailed daily report on the progress of the work including inspection records, personnel on the work site, equipment used and weather conditions as required by contract.

O12.1 Recommendation:
Contract requirements shall be enforced or updated.

O13.0 Observation:
Timing in the various SGS Fire Services logging systems was not consistent.

(NOTE: Though not related to the mishap itself, the various times for events associated with the mishap were inconsistent across the various SGS Fire Services electronic logging systems, such as the fire alarm system, 911 emergency system, and the dispatcher log. The timing inconsistency between systems hindered the development of a timeline of events associated with the VAB fire.)

O13.1 Recommendation:
All JCCC alarm and logging systems shall be synchronized on a frequent basis to maintain timing consistency.

O14.0 Observation:
Fire Fighters noted that an electrical box in the D Tower cable tunnel was hot.

(NOTE: Fire Fighters, working to locate possible sources of the heavy smoke in the D Tower cable tunnel, noted that an electrical panel (box) was indicated as very hot on the infrared detector they were using to locate potential hot spots. The panel was also noted as being very hot to the touch.)

O14.1 Recommendation:
Even though the electrical panel (box) in question may be exhibiting a normal heating condition due to high current conductors in the enclosure, electricians shall examine it to ensure that an unsafe condition does not exist.

O15.0 Observation:
Fire Fighters reported that they were receiving electrical shocks while fighting the fire on the M/N Section roof which supported their theory of an electrical fire.

O15.1 Recommendation:
Provide awareness that personal may receive mild electrical shocks after walking on, or coming in contact with recently installed static charged roofing membrane surface.

O16.0 Observation:
The mutual aid agreements established with local area fire departments were utilized during the VAB roof fire and worked according to plan. PAFB and Titusville fire departments were requested to backfill KSC and CCAFS fire stations.

O16.1 Recommendation:
None.

O17.0 Observation:
The SGS solicitation and corresponding HRI contract contained requirements that were not clearly defined.

O17.1 Recommendation:
SGS shall review and revise all solicitations and contracts to clarify requirements that have not been clearly defined and to correct inconsistencies that exist within contract documents. All NASA KSC and contractor organizations writing solicitations and contracts shall review their documents to ensure discrepancies are corrected.

SECTION IX

DEFINITION OF TERMS AND ACRONYMS

Authority Having Jurisdiction (AHJ): The AHJ is the organization, office, or individual responsible for approving equipment, an installation, or a procedure. The AHJ's are to be designated for fire protection and explosives by the Center Director. The fire protection AHJ shall be a safety or fire protection professional.

Cause: An event or condition that results in an effect. Anything that shapes or influences the outcome.

Cause – Effect Fishbone Diagram: A graphic representation of the mishap or close call that shows the event (accident) on the right end of a large arrow, identifies the main categories of causes of the problem on branches emanating from the large arrow, and lists possible causes in the applicable area(s) of the chart to determine the most likely root causes.

Condition: Any as-found state, whether or not resulting from an event, that may have safety, health, quality, security, operational, or environmental implications.

Contractor Safety Plans: Written plans prepared by the contractor detailing the overall safety program that will cover the employees, equipment, and facilities used to fulfill the contract.

Contributing Factor: An event or condition that may have contributed to the occurrence of an undesired outcome but, if eliminated or modified, would not by itself have prevented the occurrence.

Controlled Access Zone: An area in which certain work may take place without the use of guardrail systems, personal fall arrest systems, or safety net systems and access to the zone is controlled.

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

Event: A real-time occurrence describing one discrete action, typically an error, failure, or malfunction. Examples: pipe broke, power lost, lightning struck, person opened valve.

Expansion Joint: A constructed joint in an assembly allowing for movement of that assembly in a controlled location, and in a controlled failure.

Finding: A conclusion, positive or negative, based on facts established during the investigation by the investigating authority (i.e., cause, contributing factor, and observation).

Flashing: A continuous sheet of impermeable material used to prevent the infiltration of water into the interior of a building. Flashing may be made of metal, plastic, rubber, or impregnated paper.

High Visibility (Mishaps or Close Calls): Those particular mishaps or close calls, regardless of the amount of property damage or personnel injury, that the Administrator, AA/OSMA, CD, Director, HQ Ops., or the Center SMA Director judges to possess a high degree of programmatic impact or public, media, or political interest including, but not limited to, mishaps and close calls that impact flight hardware, flight software, or completion of critical mission milestones.

Leading Edge: The edge of a floor, roof, or formwork for a floor or other walking/working surface (such as the deck) which changes location as additional floor, roof, decking, or formwork sections are placed, formed, or constructed. A leading edge is considered to be an "unprotected side and edge" during periods when it is not actively and continuously under construction.

Lessons Learned: The written description of knowledge or understanding that is gained by experience, whether positive (such as a successful test or mission), or negative (such as mishap or failure.

Low-Slope Roof: A roof having a slope less than or equal to 4 in 12 (vertical to horizontal).

Membrane: A sheet of material either built up or single ply which is impervious to the penetration of water.

Observation: A factor, event, or circumstance identified during the investigation that did not contribute to the mishap or close call, but, if left uncorrected, has the potential to cause a mishap or increase the severity of a mishap; or a factor, event, or circumstance that is positive and should be noted.

Parapet: The projection of an exterior wall assembly above the roof.

Property Damage: Damage to any type of government or civilian property, including, but not limited to, flight hardware, flight software, facilities, ground support equipment, and test equipment.

Proximate Cause: The event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome. Also known as the direct cause(s).

Recommendation: An action developed by the investigation authority to correct the cause or a deficiency identified during the investigation.

Root Cause: One of multiple factors (events, conditions, or organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated or modified, would have prevented the undesired outcome. Typically, multiple root causes contribute to an undesired outcome.

Safety-Monitoring System: A safety system in which a competent person is responsible for recognizing and warning employees of fall hazards. If it is impossible to perform the construction work using a conventional fall protection system (i.e., guardrail system, safety net system, or personal fall arrest system) or that it is technologically impossible to use any one of these systems to provide fall protection, the employer can use alternative designs, materials, or methods to protect against a hazard which the employer can demonstrate will provide an equal or greater degree of safety for employees than the methods, materials or designs specified in the standard.

SOPREMA: An international company specializing in the manufacture of elastomeric bitumen-based waterproofing membranes for use in construction, civil engineering, and environmental protection.

Type D Mishap: A mishap that caused any nonfatal OSHA recordable occupational injury and/or illness that does not meet the definition of a Type C mishap, or a total direct cost of mission failure and property damage of at least $1,000 but less than $25,000.

Unprotected Sides and Edges: Any side or edge (except at entrances to points of access) of a walking/working surface, e.g., floor, roof, ramp, or runway where there is no wall or guardrail system at least 39 inches (1.0 m) high. Each employee on a walking/working surface (horizontal and vertical surface) with an unprotected side or edge which is 6 feet (1.8 m) or more above a lower level shall be protected from falling.

Warning Line System: A barrier erected on a roof to warn employees that they are approaching an unprotected roof side or edge, and which designates an area in which roofing work may take place without the use of guardrail, body belt, or safety net systems to protect employees in the area.

Witness Statements: A verbal or written statement from a witness that describes his/her account including a description of the sequence of events, facts, conditions, and/or causes of the mishap, which is considered privileged and is only releasable to the investigating authority and not the public or other government agencies unless release is ordered by a court of law.

Witness: A person who has information, evidence, or proof about a mishap and provides his/her knowledge of the facts to the investigating authority.

Acronyms and Abbreviations

ACM - Access Control Monitor

AHJ - Authority Having Jurisdiction

CFR - Code of Federal Regulations

CoF - Construction of Facilities

CT - Crawler Transporter

CTC - Chief Test Conductor

ET - External Tank

HRI – Hamilton Roofing Inc.

IR – Infrared

JCCC - Joint Communication Control Center

KCCS - Kennedy Complex Control System

KDP–P – Kennedy Documented Procedure – Procedure

KDP-F – Kennedy Documented Procedure – Form

KNPR – Kennedy NASA Procedural Requirements

KSC – Kennedy Space Center

LBS - Load Break Switch

LCC – Launch Control Center

MLP - Mobile Launcher Platform

NASA - National Aeronautics and Space Administration

NFPA - National Fire Protection Association

NPR – NASA Procedural Requirements

NTD - NASA Test Director

OIS - Operational Intercommunication System

OPF - Orbiter Processing Facility

OSHA - Occupational Safety and Health Administration

OTC - Orbiter Test Conductor

OV- Orbiter Vehicle

PAFB - Patrick Air Force Base

PLC - Programmable Logic Controller

SBS – Styrene-Butadiene-Styrene

SGS – Space Gateway Support

SPDMS - Shuttle Processing Data Management System

SRB – Solid Rocket Booster

SRM - Solid Rocket Motor

SS – Substation

UA - Utility Annex

UPS - Uninterruptible Power System

USA - United Space Alliance

USS - Unit Substations

VAB – Vehicle Assembly Building

VFI - Vacuum Fault Interrupt

Volume II Data

SOPREMA®

310 Quadral Drive
Wadsworth, Ohio 44281
330-334-0066
330-334-4289 Fax

February 2, 2005

Tom Brophy
Space Gateway Support LLC
P. O. Box 21237 M/CSGS 127
Kennedy Space Center, Florida 32815

Re: VAB Building
M & N Level
Soprema Roofing

Dear Tom:

This will reference the following issues, which have been discussed:

1. Soprema has a 25-year plus history in manufacturing its SBS roof materials.

2. Hamilton Roofing is a certified Soprema installer and has been enrolled in Soprema's program for over 10 years.

3. Soprema's self adhered flashing systems and adhesive bonded flashing systems meet its 20-year warranty program requirements.

4. Hamilton Roofing personnel have been fully trained and certified to install torch applied systems by Soprema. The following is the list of personnel who have been trained and certified:

Tony Hamilton	Albaro Zamora
Louis Smith	Jose Garcia
Shawn Smith	Ricardo Hamilton
Willie Williams	Juan Ambriz
Alvin Waite	Chris Glynn
David Wright	Arturo Moreno
Harlen Williams	Jorge Magna

Please review and advise whether you have any questions.

L. J. Rauktis
Regional Manager

HAMILTON
ROOFING
INCORPORATED

7065 Osage Street, Palm Bay, FL 32909 TEL: (321) 729-0548 FAX: (321) 725-2029
P. O. Box 500590, Malabar, Florida 32950 email:
hamiltonroofing@usa.net

February 4, 2005

Space Gateway Support, LLC
P.O. Box 21237
Kennedy Space Center, FL 32815-0237
Attn.: Mr. Rich Scredon

RE: Hamilton Roofing Personnel Training Procedures

Our manufacturers have trained Hamilton Roofing's key people in Torch Down Roofing and Hot Asphalt Applied Roofing. Our newly hired employees and or employees that have progressed in experience have been taught those same procedures by our key people with an "on the job program".

Hamilton Roofing's employees are also taught Safety Awareness which consist of all phases of roofing. In addition to our safety meetings we have weekly toolbox safety meetings, which are held on the job site.

Also, please be advised that on February 15, 2005, Hamilton Roofing and our foremans will be attending a CERTA training the trainer class put on by NRCA & CNA Insurance. This is a ten-hour class to certify our foremans to train the people under them to CNA Insurance standards. CERTA is national Torch Applied Application Certification that is offered by our insurance company for torch safety. We also have two inferred hand held guns that will be used on all jobs by the foremans. We are in the process of purchasing an inferred camera to be used in lieu of the guns. I have been in contact with Kathryn Knettel of your organization to help us in the purchase of this inferred camera.

If I can be of any further assistance please feel free to call me at 321-427-8700.

Respectfully,

Anthony Hamilton
President

SGS Interim Specifications

Sample Specification Requirements

1.1 Torch Applied (Heat Weld) Modified Bitumen Membrane Safety

SBS Modified Bitumen Products applied at KCS and CCAFS may require the use of an open flame propane torch. Improper use of these materials and application equipment can result in severe burns, and/or other physical injury, as well as damage to property. In order to prevent these situations, the mechanic must install the materials using the techniques recommended by "A Guide to Safety: Torch-On Modified Bitumens" available from the (ARMA) Asphalt Roofing Manufacturers Association. These techniques have been endorsed by the National Roofing Contractors Association and the United Union of Roofers, Waterproofers and Allied Workers.

1.1.1 Protection of Property

1.1.1.1 Protective Coverings

Install protective coverings (i.e. fire retardant blankets and/or shield) at building walls, eaves, parapets and equipment curbs constructed of combustible materials within 3 feet of the area of work prior to commencing the work. Lap protective coverings not less than six inches and secure against wind. Keep protective coverings in place for the duration of the roofing work.

1.1.1.2 Applicator's Certification

The Roofing contractor must ensure that all mechanics or applicators involved with the application of heat welded modified bitumen are properly trained not only in application and equipment handling, but safety measures. The contractor should verify that all roofing applicators involved with open flame application maintain and carry a valid Certified Roofing Torch Applicator ("CERTA") card as evidence of proper training.

1.1.1.3 Open Flame Application Equipment

Torches and other open flame equipment shall be specifically designated for use in application of modified bitumen and approved by the modified bitumen sheet manufacturer. Open flame equipment shall not be ignited (burning) when left unattended. Provide and maintain a fire extinguisher adjacent to open flame equipment on the roof. Specific requirements for fire watches and burn permits exist. These requirements will be outlined at the pre-roofing conference.

1.1.1.4 Fire Watch

Provide fire watch personnel during torch application and continue for one hour after completion of torch application.

Provide at least one certified infrared heat detection gun per torch for use during the fire watch to verify cool, safe and a non-combustible conditions exist.

Provide at least two 2½ gallon containers of water and two 20 pound ABC (dry chemical) extinguishers per torch for use during the fire watch.

Check all fire extinguishers prior to and at the completion of the day's work to make sure they are full and operable.

1.1.1.5 Materials at the Jobsite

Stored flammable materials, materials covered with shrink wraps, materials covered with craft paper and/or tarps should kept a minimum of 35 feet from all torch/welding applications. Combustible materials requiring direct covering by the Torch-On Modified Bitumens system, shall be installed as specified in Division 7 Section 07550 "Modified Bituminous Membrane Roofing" unless specified or recommended otherwise as per manufacturer's printed application instructions, NRCA CD, NRCA R&W Manual for "cold adhered" materials over the combustible roof materials.

1.1.1.6 Windy Conditions

During applications, where cross winds are occurring, the use of torching machines with side shields shall be used to prevent flame distortion of the end burners.

Torch machine equipment with bottom shield plate shall be used to prevent the flame spread on to roof deck and substrate.

Where heavy wind gust of 15mph are present the use of all torching equipment shall cease and desist until wind gust conditions come to an end and/or notification form the safety engineer.

Lessons Learned

O18.0 Observation:
KDP–KSC-P-1474, "Mishap Investigation Board" and KDP-KSC-F-1474, "Mishap Investigation Report" are not consistent with NPR 8621.1A, "NASA Procedural Requirements for Mishap Reporting, Investigating, and Recordkeeping", dated February 11, 2004.

(NOTE: KDP-KSC-P-1474 and KDP-KSC-F-1474 do not address proximate causes or ex-officio board members which are addressed in NPR 8621.1A. KDP-KSC-F-1474 makes reference to NPD 8621.1 and NPG 8621.1, neither of which exists today.)

O18.1 Recommendation:
Revise KDP-P-1474 and KDP-F-1474 to be consistent with the requirements of NPR 8621.1A.

O19.0 Observation:
Logistical and administrative support, and training identified in KDP-P-1474 were not provided.

O19.1 Recommendation:
Provide the following resources to all Mishap Investigation Boards:

1. A secure room/facility in which to conduct the investigation. This room should have a cipher lock to allow access for all board members. Items to be provided in the meeting room should include:
   a. At least one up-to-date computer with Microsoft Office products, full internet access, CD reader and CD writer, black and white and color high speed printers
   b. Computer projection of the computer listed above to allow group reviews
   c. Standard workstation with full internet access to allow board members to conduct on-line research and check e-mail
   d. Routine office supplies (binders, folders, pens, pencils, stapler, paper clips, dictionary, post-it notes, etc.)
   e. High speed copier
   f. Speaker phone with conference calling capability
   g. Fax machine
2. Digital camera
3. Voice recording equipment (recorder and blank media) and transcription service to facilitate the witness interview process.

O19.2 Recommendation:

Develop a training session on board procedures and present it to all Mishap Investigation Board members within 48 hours of appointment. Board Chairperson and Ex-Officio shall have applicable training prior to appointment.