NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

August 20, 2003

Report of Medical Investigation

DCA02MA054

A. ACCIDENT

Operator:	Federal Express Corporation (FedEx)
Location:	Tallahassee, Florida
Date:	July 26, 2002
Time:	0537 eastern daylight time
Airplane:	Boeing B-727-200, N497FE

B. INVESTIGATOR

Mitchell A. Garber, M.D., M.P.H., M.S.M.E.
Medical Officer
National Transportation Safety Board
490 L'Enfant Plaza East, SW
Washington, DC 20594

C. SUMMARY

On July 26, 2002, about 0537 eastern daylight time, a Boeing B-727-232, N497FE, operating as FedEx flight 1478, crashed into trees on short final approach to Runway 9 at the Tallahassee Regional Airport (TLH), Tallahassee, Florida. The flight was operating under provisions of Title 14 Code of Federal Regulations Part 121, as a scheduled cargo flight from Memphis, Tennessee (MEM) to TLH. Night visual meteorological conditions prevailed at the time of the accident. The three flight crewmembers were injured, two seriously, and the aircraft was destroyed by the impact and resulting fire.

D. DETAILS OF THE INVESTIGATION

The Medical Officer coordinated with the Chairman of the Cockpit Voice Recorder Group on the evaluation of apparent breath sounds audible from the first officer's (F/O) microphone throughout much of the CVR recording (see Sound Study in public docket).

The Medical Officer reviewed pre-accident medical records maintained on the F/O by the Federal Aviation Administration, the U.S. Navy, and his personal physician,

and the F/O's post-accident medical records from two different hospitals, obtained through release from the F/O. Pertinent material from these records is detailed below.

The Medical Officer coordinated consultant evaluation of the F/O's post-accident chest radiographic studies, with the F/O's concurrence. The evaluation was performed by The head of the Cardiopulmonary Division of the Duke University Medical Center Department of Radiology. Pertinent material from the evaluation is detailed below.

The Medical Officer coordinated an aeromedical evaluation of the F/O's color vision at the Aeromedical Consultation Service of the U.S. Air Force School of Aerospace Medicine at Brooks City-Base, Texas. The report of this evaluation is attached (Appendix G)

E. FACTUAL INFORMATION

1. First Officer (pre-accident) FAA Medical Records

A letter dated 7/25/95 from the F/O's Aviation Medical Examiner "To whom it may concern" notes "A physical exam was done today on a 37 year old Navy pilot with fifteen years military service. He has 3600 hours of flight time. He was found to have color vision loss on pseudoisochromatic plates missing numbers 3,4,5, and 6. This suggests mild red-green defect. Per your instructions I gave him his certificate and am sending FAA form 8500-8 to your office rather than Oklahoma City. Please notify me about any SODA number that he is issued."

A letter dated 8/1/95 from an FAA Regional Flight Surgeon to the F/O notes "… based on your operational experience, I have determined that you are eligible for a first class medical certificate along with a Statement of Demonstrated Ability (waiver) for defective color vision. …"

The F/O's most recent Report of Medical Examination dated 10/9/01 notes "yes" for Item 23 "Statement of Demonstrated Ability (SODA)" and "Fail" under Item 52 "Color Vision." Under "Comments on History and Findings the report notes "Color Deficient."

2. First Officer (pre-accident) U.S Navy Medical Records

Annual reports of examinations performed on the First Officer from 1979 through 1995 consistently recorded 20/20 or better near and distant visual acuity in both eyes without correction. Color vision testing performed in conjunction with all but 3 of these examinations was recorded as "passed," usually specifying the Farnsworth Lantern (FALANT) Color Perception

Test[1] with a score of 9/9. See figure for a photograph of a Farnsworth Lantern. The most recent examination was dated 10/6/95 and noted 20/20 near and distant visual acuity and "FALANT passed 9/9."

3. First Officer (pre-accident) Personal Medical Records

A physician's note dated 7/22/02 indicates "States injured left knee – 6 weeks ago playing basketball – pain behind knee. … Left knee no swelling or crepitus – full range of motion – some tenderness posterior palpation … Assessment … Left knee pain … Plan – X-ray … referral for orthopedic evaluation." Records did not indicate any X-ray or orthopedic evaluation performed before the accident.

4. First Officer (post-accident) Hospital Records (first hospital)

After the accident, the F/O was treated at a local hospital from 7/26/02 until 8/8/02. The records from that hospitalization document significant chest injuries treated primarily with the insertion of bilateral chest tubes. The records also document hypoxemia and right lower lobe lung consolidation throughout the hospitalization. See Appendices A through C for detailed extracted medical records.

5. First Officer (post-accident) Hospital Records (second hospital)

After his discharge from the local hospital providing initial treatment, the F/O traveled to his home. He was subsequently admitted through the emergency room to a hospital near his home where he was treated from 8/10/02 through 8/23/02. The records from that hospitalization document infection surrounding his right lung treated with thoracotomy and evacuation, a small tear in his left hemidiaphragm repaired surgically, and a large right pulmonary embolus and bilateral small pulmonary emboli treated with anticoagulation. See Appendices D and E for detailed extracted medical records.

6. Consultant Radiologist's Reports

The head of the Cardiopulmonary Division of the Duke University Medical Center Department of Radiology (radiology consultant), was asked to review of all of the F/O's chest radiographic studies performed at the local hospital in which he was initially treated after the accident to determine whether there was sufficient evidence to confidently rule out or diagnose a pulmonary embolus in the F/O, or whether there was insufficient evidence to make a determination either way.

The radiology consultant's response noted, in part: "In regards to the questions of whether or not evidence exists for pulmonary embolism there are some areas that would

[1] The Farnsworth Lantern test presents the examinee with 9 pairs of colors (green and red filters which are known to be confused by color vision deficient individuals are used, along with unfiltered white light). Each of the three colors (red, green, or white) can be presented in either the top or bottom position, resulting in 9 different possible combinations. Filters are used to vary light intensity among pairs of the colors, preventing the use of light intensity alone to identify color.

certainly be compatible with that diagnosis. … Other areas of homogeneous opacity…on the study performed 7/31/02 could represent pulmonary embolism although not strictly characteristic and more likely secondary to pneumonia. Pleural fluid is also seen in patients with pulmonary embolism and this patient had right pleural fluid at least on CT scanning and probably left pleural fluid seen initially following trauma. Direct evidence of pulmonary embolism is not identified on the examination however. That is there is not enough opacification of pulmonary arteries to reliably assess the presence or absence of peripheral pulmonary embolism. No definite filling defects of the more central pulmonary arteries… interlobar arteries… [and] some of the proximal segmental branches. In the absence of filling defects in these structures no definite pulmonary emboli are identified. … On one image 20 [from the CT scan performed 7/31/02] the possibility of central filling defect in one of the right upper lobe vessels is raised … there is insufficient evidence to make a determination either way that pulmonary embolism is present or absent.

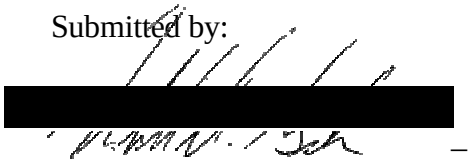
After the medical consultant had completed the above review, he was provided copies of chest CT scans performed during the F/O's second hospitalization following the accident. The medical consultant was asked to determine whether the additional review suggested any evidence of or evidence ruling out the existence of pulmonary emboli on the F/O's initial admission.

The medical consultant noted, following the review of the additional CT scans, "Having reviewed a pulmonary embolism protocol CT scan performed on [the F/O] on 8/16/02, I believe it is possible that a small filling defect seen in one of the right upper lobe pulmonary arteries on the previous CT scan of 7/31/02 may in fact have represented a small pulmonary embolus. This interpretation is made only in retrospect." See Appendix F for comprehensive extracted pertinent material from the medical consultant's reports.

7. First Officer Color Vision Evaluation

The report of evaluation from the U.S. Air Force Aeromedical Consult Service Ophthalmology Branch notes in part that, "the type and degree of [the F/O's] congenital red-green defect could result in difficulties interpreting red-green and white signal lights that combine color and brightness, such as PAPIs and VASIs." The evaluation notes that the F/O likely employed "learned strategies, other than normal color discrimination, to 'interpret' PAPIs." The complete report is included as Appendix G.

Submitted by:



Mitchell A. Garber
Medical Officer
August 20, 2003

APPENDIX A
First Officer Hospital Records (first hospital - notes)

APPENDIX A

The following pertinent medical information was extracted by Dr. Mitchell Garber, NTSB Medical Officer, from the medical records maintained on the First Officer at the local hospital which treated him immediately following the accident:

Date (time)	Information
7/26/02 (0620)	Emergency Medical Service note states "Dispatched code 3 to airport for plane crash. On arrival patient states he was First Officer in 727 FedEx crash. Patient states remembers final approach, does not remember actual crash. Positive loss of consciousness. Positive left mid back pain. … Per crewmembers loss of consciousness was less than 2 minutes … Patient on arrival ambulatory, alert and oriented x 3, confused about recent events. … oxygen 10 L/ min non-rebreather mask …"
7/26/02 (0802)	Laboratory report notes hemoglobin 15.3 g/dL, hematocrit 44.8%
7/26/02 (1700)	"ER admit note" states: "44 year old pilot involved in plane crash this morning. Patient with questionable loss of consciousness as does not remember events. Patient complains of left chest and shoulder pain. ER physicians evaluated with multiple CTs and X-rays with negative head CT, negative abdominal CR, rib fractures of T2-6 with hemopneumothorax on left and small right hemothorax, also with bilateral pulmonary contusions left greater than right. … Plan … left chest tube …"
7/27/02	Surgeon's note indicates "Patient up and more animated/active. … Chest … increased excursions from yesterday … will culture sputum and begin Unasyn [ampicillin/sulbactam]. Increase pulmonary toilet. Add nebulizers. … increase activity." Laboratory report notes hemoglobin 13.7 g/dL, hematocrit 39.4%
7/28/02	Surgeon's note indicates "Maximum temperature 39.4. Poor cough … Chest – decreased breath sounds left more than right base. Patient spiked fever yesterday …oxygen saturation 93% - increased to 97-98% with coughing, deep breathing. … Need to ambulate patient more. Needs vigorous pulmonary toilet."
7/30/02	Surgeon's note indicates "Patient with oxygen saturation 92-93%. Chest X-ray – left lung aeration has improved, right chest with obvious increased fluid. Will place right chest tube. …" "Procedure note" for "Right chest tube insertion" indicates "…Findings … (1) Pleural adhesions (2) approximately 400 cc fluid initially evacuated."
7/30/02 (1915)	"Addendum" indicates "Chest tube replaced lateral … another 500 cc fluid obtained …"
7/30/02 (1930)	Pulmonary consult notes pilot is "smoker ½pack per day … active at gym, does aerobics. No premorbid cough, sputum, hemoptysis, pleurisy. No premorbid chest pain …Exam: heavily sedated, snores when asleep but no obstruction observed … oxygen saturation 92% on 50% mask and 6 L/min nasal prongs. Bilateral chest tubes no air leak. … No deep vein thrombosis …" "Plan" notes "… inspired oxygen to keep saturation above 90%,

	heparin 5000 units subcutaneously every 12 hours."
7/31/02	Surgeon's note indicates "…Right chest tube 650 cc total since placed (total 1100 …) left chest tube approximately 60-70 cc overnight – chest tube removed. … Patient is better clinically." Laboratory report notes hemoglobin 12.8 g/dL, hematocrit 37.8%. Pulmonologist note indicates "…maximum temperature 100.5 …"
8/1/02	Laboratory report notes hemoglobin 11.6 g/dL, hematocrit 34.0%
8/2/02	Surgeon's note indicates "Afebrile, vital signs stable. No air leak – chest tube out….increase ambulation." Pulmonologist note indicates "… bilateral lung contusion, hemothorax show gradual improvement. …" Laboratory report notes hemoglobin 12.1 g/dL, hematocrit 36.4%
8/3/02	Surgeon's note indicates "Afebrile, vital signs stable. Still on 6 L nasal oxygen – wean. …" Pulmonologist note indicates "… atelectasis, lung contusion …"
8/4/02	Surgeon's note indicates "Afebrile, vital signs stable. Oxygen saturation 93% on 3 ½L nasal oxygen. …. Right pleural effusion on chest X-ray 8/2. …" Pulmonologist note indicates "… persistent right pleural effusion …"
8/5/02	Laboratory report notes hemoglobin 10.8 g/dL, hematocrit 32.0%
8/6/02	Pulmonologist note indicates "… oxygen saturation 90s on 2 L … Assessment – slowly better .."
8/7/02	Surgeon's note indicates "….will plan for discharge tomorrow. …oxygen to have in airplane."
8/7/02	Physician orders note "… discontinue subcutaneous heparin. …"

APPENDIX B
First Officer Hospital Records (first hospital – oxygenation status)

APPENDIX B

The following information regarding the First Officer's post-accident oxygenation status was extracted by Dr. Mitchell Garber, NTSB Medical Officer, from the medical records, particularly respiratory therapy notes, maintained on the First Officer at the hospital which treated him immediately following the accident. Where it was noted, the route of oxygen delivery and heart and respiratory rate are included. Respiratory and heart rates are before any nebulizer treatments in all cases.

Date (time)	O_2 saturation	Resp. Rate	Heart Rate	O_2 delivered (route)	Notes
7/26/02 (0620)	100%	16	86	10L/min (non-rebreather mask)	
7/26/02 (0638)	100%	16	99	undocumented	Upon triage in ER
7/26/02 (0730)	96%	16	85	4L/min (nasal cannula [NC])	Administered "Dilaudid 1mg IV" at 0655
7/26/02 (0800)	96%	20	85	4L/min (NC)	Administered "IV Morphine Sulphate"
7/26/02 (1000)	94%	24	85	4L/min (NC)	
7/26/02 (1130)	94%	12	90	3L/min (NC)	"… pain decreased to 2.5/10 …"
7/26/02 (1230)	100%	20	96	3L/min (NC)	"Declines offer of pain med – 2.5/10"
7/26/02 (1330)	100%	16	88	3L/min (NC)	
7/26/02 (1420)	99%	16	88	3L/min (NC)	"Sleeping"
7/26/02 (1600)	96%	13	84	5L/min (NC)	"Patient saturations decreased to 92%. Increased oxygen to 5 L via NC. … Pain at 2. Sleeping …"
7/26/02 (1745)	99%	9	82	5L/min	Beginning insertion of left chest tube (sedated)
7/26/02 (1830)	97%	11	84	5L/min	Following insertion of left chest tube
7/26/02 (1915)	95%	18	81	5L/min	
7/27/02 (0500)	96%	18	80	5L/min (NC)	"Incentive spirometry instructions given. Patient performed with fair effort but complained 'too painful.' …"
7/27/02 (0815)	91%	20	81	5L/min	"Patient up in chair …"
7/27/02 (1030)	90%	24	93	5L/min/Venturi mask (VM)	"Patient decreases oxygen saturation 88%. Added Venturi mask. …"
7/27/02 (1500)	88%	36	100	Venturi mask	"Patient with shaking chills and fever. …"
7/27/02 (1945)	93%	20	87	Not noted	
7/28/02 (0600)	88%	28	98	6L/min (NC)	"Increase to 50% Venturi mask"
7/28/02 (0730)	94%	20	88	50% (VM)	
7/28/02 (1155)	94%	20	90	5L/min (NC)	

7/28/02 (1700)	94%	20	90	5L/min (NC)	
7/28/02 (2010)	95%	24	105	50% (VM)	
7/29/02 (0615)	96%	20	84	50% (VM)	"Patient sleeping with no distress"
7/29/02 (0730)	97%	21	84	50% (VM)	"…moved from 50% VM to 6L/min."
7/29/02 (1330)	88%	20	109	6L/min (NC)	"…sitting…in chair … saturation decreased to 84% on 6L/min NC, increased to Venturi mask at 50%, saturation increased to 96%."
7/29/02 (1650)	98%	16	93	50% (VM)	
7/29/02 (2130)	94%	20	96	6L/min	"No distress observed…"
7/29/02 (2210)	79%	Not noted	Not noted	6L/min	"Patient placed back on NC and VM due to decreased saturation reading …"
7/30/02 (0050)	84%	22	110	6L/min and 50% (VM)	"No distress …"
7/30/02 (0455)	92%	22	120	6L/min and 50% (VM)	"Patient coughed up large amount of thick brown secretions and right lower lobe aeration is much better."
7/30/02 (0710)	95%	20	101	50% (VM)	
7/30/02 (1225)	95%	16	102	6L/min and 50% (VM)	
7/30/02 (1600)	93%	24	114	6L/min and 50% (VM)	
7/30/02 (2130)	95%	24	104	6L/min and 50% (VM)	
7/30/02 (2245)	Not noted	24	103	75% (MO ["Misty-Ox mask"])	"Patient placed on Misty-Ox mask to provide increased aerosol to help thin the thick secretions and provide high inspired oxygen …"
7/31/02 (0055)	77%	Not noted	Not noted	75% (MO)	"Patient has trouble remembering to keep oxygen mask on. Nasal cannula placed on for backup."
7/31/02 (0330)	96%	22	90	75% (MO) and 6L/min	"Patient awake and sitting on side of bed. …"
7/31/02 (0455)	89%	Not noted	Not noted	6L/min (NC)	"Patient's saturations decreased while sleeping and MO mask added to NC."
7/31/02 (1015)	94%	24	108	6L/min	
7/31/02 (1600)	95%	28	105	6L/min	
7/31/02 (2130)	94%	20	106	6L/min	
8/1/02 (0820)	89%	22	111	6L/min	"Changed to 40% face mask for humidity for thick secretions and increased oxygen saturation."
8/1/02 (0915)	91%	22	107	6L/min	
8/1/02 (1110)	97%	24	100	40% face mask	"asleep…"

8/1/02 (2045)	92%	24	106	6L/min (NC)	
8/2/02 (0035)	93%	Not noted	Not noted	6L/min	"…patient was asleep"
8/2/02 (0850)	Not noted	18	124	5L/min	
8/2/02 (1600)	94%	20	118	5L/min	
8/2/02 (2115)	84%/94%	20	100	Room air/50% (VM)	
8/3/02 (0815)	94%	22	94	5L/min (NC)	
8/3/02 (1200)	96%	24	100	5L/min (NC)	
8/3/02 (1600)	93%	22	98	5L/min (NC)	
8/3/02 (1930)	97%	18	95	5L/min	"Patient is awake and alert."
8/4/02 (0720)	95%	20	96	5L/min	
8/4/02 (1145)	96%	20	96	3½L/min	
8/4/02 (1530)	94%	24	100	4L/min	
8/4/02 (1920)	94%	28	98	4L/min	
8/5/02 (0630)	94%	Not noted	Not noted	4L/min	
8/5/02 (0715)	91%	28	101	4L/min	
8/5/02 (1135)	97%	24	88	3L/min	
8/5/02 (1605)	95%	26	99	3L/min	
8/5/02 (1940)	95%	16	92	3L/min	
8/6/02 (0810)	96%	18	94	3L/min	
8/6/02 (1230)	95%	22	94	2L/min	
8/6/02 (1625)	95%	20	93	1.5L/min	
8/6/02 (1935)	92%	Not noted	Not noted	2L/min	
8/7/02 (0445)	95%	22	92	1.5L/min	
8/7/02 (0635)	94%	Not noted	Not noted	1.5L/min	

APPENDIX C
First Officer Hospital Records (first hospital – chest radiographic reports)

APPENDIX C

The following information was extracted by Dr. Mitchell Garber, NTSB Medical Officer, from the reports of all chest radiographic procedures found in the medical records maintained on the First Officer at the hospital which treated him immediately following the accident:

Date (time)	Radiologic procedure	Indication	Findings
7/26/02	CT scan of the chest with contrast	Not noted	"Diagnosis: 1. Moderate pneumothorax involving the left lung associated with minimal hemothorax. Rib fracture seen posteriorly proximal thirds. The third and fourth ribs appear involved by the fracture described. Mild displacement. Associated with the pneumothorax, there is a minor degree of subcutaneous emphysema laterally. Other rib fractures are seen along the lateral aspect of the left hemithorax. Standard radiograph of ribs could be considered for further evaluation. 2. Sternum and scapula intact. 3. Minor fluid-atelectasis base of the right lung."
7/26/02	Portable CXR	"Accident"	"A single portable view demonstrates multiple left paramedian upper rib fractures posteriorly and several displaced lateral left sided rib fractures inferiorly. Increased lucency at the left lung base at the costophrenic angle suggests a small pneumothorax. Cardiac silhouette is at the upper limits of normal in size. There is mild fullness of the superior mediastinum perhaps related to portable supine technique. Please refer to CT report."
7/26/02 (1650)	Portable CXR	Not noted	"Redemonstrated are multiple left sided rib fractures with subcutaneous emphysema in the left lateral chest wall inferiorly. No mediastinal shift."
7/26/02 (1830)	Portable CXR	Not noted	"There has been interval insertion of a left thoracotamy tube. No definite pneumothorax. Subcutaneous emphysema remains within the lateral chest wall."
7/26/02	CT scan of the	"Accident"	"There are multiple paramedian rib fractures

	thoracic spine		on the left, including the left third to sixth ribs. There is a left pleural effusion and bilateral consolidation. Please note that the lungs are not completely visualized. A pneumothorax is not excluded. The thoracic spine is intact. No acute fractures or traumatic subluxations."
7/27/02	Portable CXR	"Shortness of breath with chest tubes. Pneumothorax"	"Left chest tube in place and there is no pneumothorax. Small infiltrate seen in the posterior basal segment of both lower lobes. Cardiovascular silhouette is normal."
7/28/02	Portable CXR	"Shortness of breath"	"There is seen partial atelectasis of the right lower lobe associated with a small amount of right pleural fluid. Left chest tube in place and the left lung is clear. Overall the findings in the right lower lobe are worse now than on the previous examination of 7/27/02. There also appears to be rib fractures in the lower left ribs. There is no pneumothorax or pneumomediastinum."
7/29/02	Portable CXR	"Chest pain"	"There is again identified a moderate degree of consolidation of the right lower lobe associated with a small amount of right pleural fluid and in fact, appearing worse now than on the previous examination. This tube is in the left pleural space with a few platelike atelectasis remaining in the left lower lobe associated with several rib fractures."
7/29/02	Portable Frontal CXR – "right lateral decubitus view only"	"follow-up after chest tube placement"	"lateral decubitus view demonstrates a left sided chest tube that appears appropriately placed. There is extensive subcutaneous emphysema within the left lateral thoracic wall and multiple widely displaced rib fractures. No definite pneumothorax at this time. No progression appreciated since prior study of subcutaneous emphysema."
7/30/02	Portable CXR	"Pleural fluid"	"A moderate amount of right pleural fluid is developing since the previous examination. This is associated with atelectasis of the right lower lobe. The platelike atelectasis in the left lung, specifically the left lower lobe, are clearing. Chest tube in the left pleural space and multiple left rib fractures are identified."
7/30/02 (1741)	Portable CXR	Not noted	"Consolidation again seen in the right lower lobe. Moderate sized alveolar infiltrate seen in the left lower lobe with the left chest tube

			in place. No change from previous examination."
7/30/02	Portable CXR	"Chest tube placement"	"Consolidation in the right lower lobe is seen with chest tube in the right pleural space. There is no change from the previous examination. Moderate sized infiltrate remains in the left lower lobe as well."
7/31/02	Portable CXR	"Shortness of breath"	"Chest tube in the right pleural space. There is no pneumothorax but significant consolidation of the right lower lobe is seen unchanged from the previous examination. Left chest tube in place and there is no pneumothorax and a moderate sized alveolar infiltrate is seen in the basal segments of the left lower lobe and overall no significant change has occurred since the previous exam."
7/31/02	CT scan of the chest with contrast	"status post blunt trauma with bilateral pulmonary contusions and persistent abnormal chest x-ray."	"Lung windows: there has been interval placement of a right sided chest tube. There is a hydropneumothorax on the right at this time with a greater fluid component than air component with increase in right-sided pleural effusion compared to prior as well as increasing pulmonary consolidation in the posterior base. There are more extensive air bronchograms throughout the larger area of consolidated lung in the posterior right lung base. There are peripheral areas of ground glass opacity in the peripheral right upper lobe and also in the anterior left upper lobe/lingual, as seen previously and likely related to pulmonary contusions. The extensiveness of subcutaneous emphysema along the lateral left thoracic chest wall has decreased wince the prior study. Again seen are multi-level displaced rib fractures of the left superiorly in the posterior third and fourth ribs on the left and multiple lateral margin fractures of the more lower thoracic ribs on the left. Persistent left pneumothorax without significant change. Small mediastinal lymph nodes are now seen in the precarinal and left paratracheal regions. These are larger than that seen on 7/26/02 and

			likely represent reactive nodes. There is relative elevation of the right hemidaphragm. The amount of pleural fluid on the left has decreased since the prior exam."
8/2/02	Portable CXR		"Redemonstrated is a right thoracotamy tube without evidence of pneumothorax. Right pleural effusion is unchanged in size. There may be some degree of underlying right lower lung consolidation as well. No definite pneumothorax."
8/2/02	CXR – PA (posterior-anterior) and lateral	"Shortness of breath and chest pain"	"The cardiomediastinal configuration appears unchanged. There has been a somewhat poor inspiratory effort. There is a large right pleural effusion. No new infiltrates are identified. The osseous structures appear unchanged."
8/5/02	CXR – PA and lateral	"pulmonary contusion"	"Consolidation of the right lower lobe is seen associated with a very small amount of right pleural fluid. The chest tube has been removed. Moderate sized alveolar infiltrate is seen in the left lower lobe but to a much lesser extent than in the right lower lobe. Comminuted, significantly displaced, left rib fractures are identified with a moderate sized extra pleural hematoma."
8/5/02	CXR with decubitus views	Not noted	"Decubitus views show very small amount of right pleural fluid and a moderate amount of extra pleural hematoma on the left side associated with the comminuted left rib fractures. Significant consolidation in the right lower lobe is seen and a small infiltrate is seen in the left lower lobe."

APPENDIX D
First Officer Hospital Records (second hospital - notes)

APPENDIX D

The following pertinent medical information was extracted by Dr. Mitchell Garber, NTSB Medical Officer, from the medical records maintained on the First Officer at the hospital near his home:

Date	Information
8/10/02	Trauma attending admission note indicates "44 year old male pilot in airplane crash 2 weeks ago … bilateral hemopneumothoraces. Left side satisfactorily managed with tube thoracostomy; right side required a total of three chest tubes, and review of chest X-rays/CTs … shows retained hemothorax despite the chest tubes. … Was discharged from hospital yesterday and patient returned to his home … today began to 'feel bad' and noticed a foul odor and drainage from one of his right chest tube sites. …" Surgical note indicates "… status post right thoracotomy for exploration and evacuation of empyema necessitans … rib excision …"
8/12/02	Surgical note indicates "… extremities – trace edema …Plan … ultrasound for deep vein thrombosis." Surgical critical care note notes medications as "Unasyn, Famotidine, subcutaneous heparin." Radiology note indicates "bilateral lower extremity ultrasound – completed."
8/15/02	Thoracic surgery note indicates "patient extubated … sitting up in bed … CT chest reviewed: empyema well drained … ? pulmonary embolus or 'flow artifact' – will need pulmonary embolus protocol CT scan … small left hemidiaphragm tear" Interval note indicates "left chest appears to show peripherally based diaphragmatic laceration …? distal right lower lobe segmental pulmonary embolus vs. flow artifact…. Plan laparoscopic investigation of diaphragm and repair … Will obtain formal pulmonary embolus protocol CT scan in morning … and anticoagulate if positive. …"
8/16/02	Surgery note indicates "Repeat CT showed ? small right pulmonary embolus and ? small left diaphragm rupture … CT pulmonary embolus protocol today … endoscopic exploration for left diaphragm tear … today … ultrasound deep vein thrombosis screen today.""
8/17/02	Surgery note indicates "…left diaphragm tear repaired … right lung pulmonary embolus being treated with heparin. …"
8/18/02	Trauma note indicates "… ? pulmonary embolus … on protocol … may need more aggressive increase given probable thrombus. …"
8/19/02	Trauma staff note indicates "…pulmonary embolus: not fully therapeutic on heparin …"
8/20/02	Trauma progress note indicates "…pulmonary embolus: therapeutic heparin, starting Coumadin. …"
8/21/02	Trauma staff note indicates "… start low molecular weight heparin (D/C IV heparin) in anticipation of discharge home Friday [8/23]. Coumadin adjustment as outpatient. …"
8/22/02	Trauma staff note indicates "… CT scan – much clearer. No extra/undrained collections. Lung parenchyma clearer. Assessment: adequately drained empyema, pulmonary embolus. Plan : 1) discontinue antibiotics, 2) convert chest tubes to empyema tubes – i.s. discontinue pleurevacs, 3) low molecular weight heparin, 4) discharge to home in morning if stable, afebrile off antibiotics

APPENDIX E
First Officer Hospital Records (second hospital – radiographic reports)

APPENDIX E

The following information was extracted by Dr. Mitchell Garber, NTSB Medical Officer, from all the reports of radiographic procedures found in the medical records maintained on the First Officer at the hospital near his home:

Date (time)	Radiologic procedure	Indication	Findings
8/10/02 (0150)	CT scan of the chest with contrast	"History of empyema. Status post chest tube removal. Arrived from Florida. Here for further evaluation"	"Comparison: limited outside CT 7/31/02. … 5 mm collimation was performed and the patient received intravenous contrast during the study. There is diffuse increasing air in the right chest wall and subcutaneous tissues. The air appears to track into the pleural space as seen on the images through the mid chest with small air bubbles seen traversing the pleural space. This becomes contiguous with a hydropneumothorax and would be compatible with the patient's known empyema. There is enhancement around the pleural surface suggesting this is infected fluid. There is a moderate amount of fluid. This surrounds consolidated or infected lung and these findings are seen on the prior exam with a similar overall extent. There is a small calcification at the right lung base which is stable. There is a scattered area of atelectasis or consolidation at the left base and small left pleural effusion and these findings are similar to the prior exam. The soft tissue windows show scattered lymph nodes in the mediastinum. Images through the upper abdomen show some granulomata in the spleen. Bone windows show rib fractures. There are significantly displaced rib fractures in the left chest with surrounding pleural fluid and hematoma. There also appears to be a discontinuity along the border of the pleura and hemidiaphragm on the left and there may be a rent in the diaphragm from the trauma."
8/10/02	CXR	"Check nasogastric and endotracheal tubes placement.	"Examination is a single view of the chest. There is right subcutaneous emphysema. The loculated air collections seen on CT are not as well seen on the plain film. There are bilateral

		History of right chest abscess."	pleural effusions. There are diffuse patchy alveolar infiltrates most pronounced in the right lower lung. There is an endotracheal tube whose tip is at the thoracic inlet. There is a nasogastric tube the distal is not seen."
8/10/02 (0634)	CXR single view	"Post operative patient. History of right empyema."	"An endotracheal tube is seen. There has been resection of right ribs since the last exam. There are bilateral densities at both bases compatible with bilateral pleural fluid and bilateral areas of infiltrate/consolidation. There is known empyema that has been treated on the right and air is seen in the right pleural space and right chest wall."
8/11/02 (1004)	CXR portable AP (anterior-posterior)	"Open chest empyema drainage"	"A single view of the chest is provided which shows persistent and possibly worsened opacification of both lung bases. This likely represents bilateral pleural effusions with atelectasis, or possibly pneumonic infiltrates. No other focal opacities or pneumothorax are seen. The pulmonary vasculature is not congested and the heart appears mildly enlarged. The mediastinum is within normal limits. The lateral portion of the right 8^{th} rib is absent. A small amount of subcutaneous gas is present on the right side. The nasogastric tube and endotracheal tube are unchanged."
8/12/02 (1024)	CXR single view portable AP	"Post dressing change and chest tube placement"	"A chest tube is in place in the right hemithorax and the linear segmental atelectatic changes in the right base where thickening of the pleura is again noted and unchanged. There is no evidence of a pneumothorax thoguth a semiupright film may misss small anterior pneumothoraces. Reduced ventilation at both bases is again seen. This appears to be unchanged. The cardiac diameter is the upper limits of normal and there is a nasogastric and an endotracheal tube seen. A second chest tube appears to be present at the right lung base and the patient has rib fractures in the right axilla. These findings were present on prior radiographs also well visualized on a CT from 8/10/02 when the patient was scanned for a right chest abscess and following trauma."
8/12/02 (1102)	Lower extremity	"Chronic immobility"	"Duplex interrogation of the lower extremity veins was performed using graded gray scale

	venous ultrasound		compression, Doppler interrogation, and color flow imaging from the level of the external iliac to the tibeoperoneal trunk. This was done portably. The vessels show compressibility, phasicity, and augmentation."
8/15/02 (0836)	CT scan of the chest with contrast	"Known empyema. Status post drainage. Follow up."	"A CT examination of the chest was performed with the use of intravenous contrast with 5 mm collimation. The patient is intubated, and there is a nasogastric tube present. There is a large left pleural effusion, which has increased since the previous study. Since the previous exam, chest tubes have been placed. There is a chest tube, which enters the right chest wall and is seen in the peripheral aspect of the right chest at the level of the left atrium. An additional tube is seen entering the right posterior aspect of the lower chest. One of these travels more caudad and one of these travels more cephalad. There is an open wound in the right posterior aspect of the chest, which appears to communicate with the pleural space. There is a large amount of air in the pleural space. The amount of fluid is less when compared to the previous study. There is associated consolidated lung with air bronchograms. The dilated air spaces within the lower lobe are not as apparent when compared to the previous study. I am uncertain if that was related to post-traumatic pneumatoceles. Some of the effusion in the left appears partially loculated. There is left lower lobe consolidation, which has increased. There are some patchy ground-glass changes in the left upper lobe anteriorly, which have improved and could represent contusion or possibly multifocal pneumonia depending on the clinical history. The right lower lobe infiltrate is slightly less apparent. There are healing left posterior rib fractures. As previously stated, there is discontinuity of the left hemidiaphragm, which suggests traumatic rupture. There is fluid and possible hematoma along the left chest wall as well as hematoma along the right chest wall. On one image, there appears to be clot within

			a right lower lobe pulmonary artery.
8/16/02 (1018)	CT scan of the chest with contrast	"Rule out pulmonary embolism"	"Axial 1.25mm CT sections through the chest were obtained following intravenous administration of contrast material using our pulmonary embolism protocol. The bolus is somewhat suboptimal and a few sections are degraded by breathing motion. However, multiple bilateral pulmonary emboli are seen. These are more profuse in the right lung. A large thrombus straddles the bifurcation of the right main pulmonary artery. Again, bilateral small effusions are noted. I suspect that these are not significantly changed. Bibasilar parenchymal opacities are noted. These could relate either to pulmonary contusions, pneumonic consolidations or atelectasis. There is a small right basilar pneumothorax which is largely unchanged. A right sided chest tube sits within it and it is unchanged. Endotracheal and nasogastric tubes have been removed in the interval from the prior exam. Healing left posterior rib fractures are again noted. There is hematoma along the left chest wall, unchanged, as well as some hematoma along the right chest wall."
8/16/02 (1556)	CXR AP upright	"Postoperative"	"Examination is a single view of the chest. There are patchy alveolar infiltrates in the lungs. The patient has documented pulmonary emboli. There are three tubes on the right. I am uncertain where these lie relative to the patient's lung. Multiple rib fractures are seen."
8/16/02 (2059)	Lower extremity venous ultrasound	"Deep vein thrombosis screen in trauma patient"	"Ultrasound with duplex interrogation of the deep venous system was performed bilaterally from the external iliac to the popliteal veins. There is normal phasicity and compressibility at all levels. Normal Valsalva and augmentation maneuvers were elicited."
8/17/02 (0849)	Portable CXR	"Pneumothorax"	"Two right sided chest tubes are seen with the tip of the least superior outside the confines of the chest wall. Right sided rib fracture is again noted. Extensive bibasilar lung opacities are seen consistent with contusion and effusion. It is difficult to appreciate pneumothorax. Heart and mediastinum are stable and midline."

8/17/02 (1350)	Portable CXR	"Questionable pneumothorax. Chest tube disconnect."	"The appearance of the chest is unchanged with bibasilar opacity. No recurrent pneumothorax. Two right-sided chest tubes noted. One, again, with the tip outside the confines of the chest wall. Right sided rib fracture seen."
8/17/02 (2241)	AP CXR	"Pneumothorax, follow-up."	"The patient shows what appears to be post thoracotomy change in the lower ribs on the right. There are two pleural drainage catheters in place, though their tips appear to lie barely within the pleural space. There appears to be a loculated pneumothorax again noted on the right at the base. There is pleural thickening and/or adjacent parenchymal consolidation within the right lower lobe. Pleural parenchymal changes persist on the left with consolidative changes at the left base and associated pleural abnormality. There are multiple left-sided rib deformities consistent with post traumatic injury. The upper lung zones remain grossly clear. It would appear that there is incomplete expansion of the right upper lobe."
8/18/02 (0009)	CXR	"Air leak, possible pneumothorax"	"The patient apparently has a known draining empyema on the right. Compared to prior exam, I see little interval change. The basilar pneumothorax is again noted. There is associated pleural thickening and parenchymal consolidation at the right base. Consolidative changes are again noted at the left base with associated pleural abnormality. Bilateral rib deformities are evident. There is incomplete expansion of the right upper lobe.
8/18/02 (0845)	AP CXR	"Dyspnea"	"Two pleural drainage catheters remain in place overlying the right lung base, though their exact location is not clear. There are bilateral pleural parenchymal changes at the bases, essentially unchanged compared to prior exam, thought there may be increasing pleural fluid at the right base. Consolidative changes are again noted. Bilateral rib deformities are evident. I do not see evidence of superimposed pulmo nary edema in the upper lung zones. Again, there appears to be incomplete

			reexpansion of the right upper lobe.
8/22/02 (1107)	CT scan of the chest with contrast	"Prior trauma, history of left diaphragmatic disruption with repair, history of multiple rib fractures, history of right-sided empyema, history of pulmonary embolus, follow-up."	"A CT examination of the chest was performed with 5 mm collimation with use of intravenous contrast. There are shotty mediastinal and hilar lymph nodes. The previously documented pulmonary emboli are not well visualized on this exam but this study was not dedicated to the evaluation of pulmonary embolus. There is suggestion of some small areas of clot but again this study is limited in its interpretation for clot. There is improved aeration of the left upper lobe. An area of previously noted alveolar consolidation (likely hematoma) in the left upper lobe is now only a small area of ground glass. There is patchy consolidation in the left lower lobe. Some of this has a liner configuration. This is slightly improved. There are multiple displaced left sided rib fractures as previously stated. There is less fluid in the region of the rib fractures. This is at the site of diaphragmatic repair. On the right, when compared to the previous study, there is less of a pleural effusion over time but there still is small amount of fluid. There is packing material in the right subdiaphragmatic region and this communicates with the chest wall. There is a loculated pneumothorax which is unchanged. There is less consolidation in the right lower lobe when compared to the previous study. Again noted are two tubes entering the right pleural space. Their tips are adjacent to each. Too small to characterize low density lesion in the dome of the liver.

APPENDIX F
Consultant Radiologist's Reports

APPENDIX F

The following information was compiled by Dr. Mitchell A. Garber, NTSB Medical Officer.

The NTSB arranged for a review of all of the First Officer's chest radiographic studies performed at the local hospital in which he was initially treated following the accident. This review was performed by Dr. Philip C. Goodman, the head of the Cardiopulmonary Division of the Duke University Medical Center Department of Radiology. Dr. Goodman was not provided any additional information regarding the accident or the F/O, and was asked to address the following specific questions:

1) Is there sufficient evidence to confidently rule out a pulmonary embolus in this patient?
2) Is there sufficient evidence to confidently diagnose a pulmonary embolus in this patient?
3) Is there insufficient evidence to make a determination either way?

The following information was extracted from Dr. Goodman's complete report, dated 2/18/03:

> In regards to the questions of whether or not evidence exists for pulmonary embolism there are some areas that would certainly be compatible with that diagnosis. In particular the peripheral, somewhat wedge-shaped opacity seen in the left lower lobe on [CT scan] images 39 and 40, lung windows, 7/31/02 could represent an area of pulmonary ischemia/infarction. Other areas of homogeneous opacity in the right lower lobe and left lower lobe medially on the study performed 7/31/02 could represent pulmonary embolism although not strictly characteristic and more likely secondary to pneumonia. Pleural fluid is also seen in patients with pulmonary embolism and this patient had right pleural fluid at least on CT scanning and probably left pleural fluid seen initially following trauma. Direct evidence of pulmonary embolism is not identified on the examination however. That is there is not enough opacification of pulmonary arteries to reliably assess the presence or absence of peripheral pulmonary embolism. No definite filling defects of the more central pulmonary arteries including right and left pulmonary artery and interlobar arteries bilaterally as well as some of the proximal segmental branches. In the absence of filling defects in these structures no definite pulmonary emboli are identified.
>
> The majority of the important films which might identify direct evidence of pulmonary embolism are missing from the study of 7/31/02. On one image 20 the possibility of central filling defect in one of the right upper lobe vessels is raised, however without contiguous images it is impossible to know for certain. Consequently there is insufficient evidence to make a determination either way that pulmonary embolism is present or absent. [The missing films were subsequently provided to Dr. Goodman, who noted in telephone conversation with Dr. Garber after reviewing them that his conclusions remained unchanged].

After Dr. Goodman had completed the above review, he was provided copies of chest CT scans performed during the First Officer's second hospitalization following the accident. Dr. Goodman was asked to address the following specific questions:

1) Is there any evidence of the existence of any pulmonary emboli on 7/26/02?
2) Is there sufficient evidence to rule out the existence of any pulmonary emboli on 7/26/02?
3) Is it possible to determine with any confidence the age of the emboli noted on the CT examinations of 8/15/02 and 8/16/02?

Dr. Goodman noted on 3/25/03 as an addendum to his report above that:

> Having reviewed a pulmonary embolism protocol CT scan performed on [the F/O] on 8/16/02, I believe it is possible that a small filling defect seen in one of the right upper lobe pulmonary arteries on the previous CT scan of 7/31/02 may in fact have represented a small pulmonary embolus. This interpretation is made only in retrospect.

APPENDIX G
(FIRST OFFICER COLOR VISION EVALUATION)

DEPARTMENT OF THE AIR FORCE
USAF SCHOOL OF AEROSPACE MEDICINE (AFMC)
BROOKS CITY-BASE TEXAS

28 Mar 03

MEMORANDUM FOR NATIONAL TRANSPORTATION SAFETY BOARD
ATTN: MITCH GARBER, M.D.
490 L'ENFANT PLAZA EAST, SW
WASHINGTON DC 20594

FROM: USAFSAM/FECO
2507 Kennedy Circle
Brooks City-Base Texas 78235-5116

SUBJECT: Mr. William Frye, SSN# [redacted]

1. The Aeromedical Consultation Service (ACS) of the USAF, School of Aerospace Medicine at Brooks City-Base Texas has completed our aeromedical evaluation on Mr. William Frye, a 44 y/o FedEx 727 pilot with a long standing known color vision (CV) deficiency who was involved in a nonfatal mishap along with two other crewmembers at Tallahassee, Florida on 26 Jul 02. Additional details regarding the final approach to Runway 09 at night and in clear weather are accounted for elsewhere; so only pertinent features related to our evaluation will be stated here.

2. Mr. Frye stated that he was at the controls of the aircraft and was using pilot-controlled PAPI lights during the approach. Although he stated that his memory lapse started about 10 miles prior to impact, he also stated that he was seeing the two white and two red light presentation on the PAPIs, but had provided "half a knob" of additional power when it appeared earlier that the aircraft was approximately one degree below glide slope. He stated that the aircraft was in a stable approach configuration, which was agreed to by all three crewmembers. He stated that he remembers continuing to see the two white and the two red light PAPI configuration. He further stated that he believed that there were indications discovered later that the PAPI lights may not have been operating optimally, but at the time of this evaluation, official verification of their operating condition was not available.

3. Historically, Mr. Frye had been a P3 Orion pilot in the Navy and had been qualified as a naval aviator on the basis of passing their primary CV screener, the Farnsworth Lantern (FALANT). At that time to our knowledge, the US Navy was not screening for CV deficiencies using Pseudoisochromatic plates (PIPs). According to routine procedures, he was requalified annually throughout his Navy flying career by the FALANT. Mr. Frye later received an FAA waiver without any flight restrictions in 1996 for his CV defect and recalls being tested with a plate test at that time.

4. At the time of the mishap, he stated that he was using over-the-counter dosage levels of Motrin for a knee injury, but could not recall the actual dose. He admitted to only taking two per day for about a 3-week period. However, as a consequence of serious injuries sustained during the mishap, he was now taking Coumadin for anti-embolic prophylaxis and Hydrocodone for pain, but had previously been on Oxycodone. He reported no other significant ocular history or medical history other than needing spectacles for near and distant vision correction.

5. The NTSB requested that CV testing at the ACS be done under pulse oxymetry to record his oxygen saturation levels during testing.

6. Examination Summary: Complete details of the ophthalmic evaluation will follow. However, a brief summary of the pertinent findings is covered in this letter. He had a small amount of myopia and presbyopia that were both correctable with spectacles to 20/15 O.U. for distance and 20/20 O.U. for near.

7. Color Vision Testing: During CV testing, his oxygen saturation was recorded to be between 98-99% by pulse oxymeter. All CV testing was performed monocularly in a darkened room under an approved illuminant and in compliance with individual test instructions and their appropriate time intervals.

a. PIP-I: Mr. Frye failed the Dvorine Pseudo-isochromatic plate test, which is a red-green congenital CV PIP screening test. To pass this test and to be regarded as color normal, an individual must have no more than four errors. On the first run, Mr. Frye could only correctly identify 2/14 correct OD and 3/14 correct OS. A repeat test, administered later, produced scores of 7/14 correct OD and 6/14 correct OS. Both of these test scores clearly reflect a failing score as per Dvorine's instructions and based on validation studies performed on that test.
b. PIP-II: Mr. Frye scored 9/10 correct in each eye on the Standard Pseudo-isochromatic Plate II (SPPII), which is a PIP test primarily optimized for acquired CV deficiencies, particularly blue-yellow. These are regarded to be passing scores on this test.
c. PIP-III: Mr. Frye scored 5/10 correct OD and 9/10 OS on the Standard Pseudoisocromatic Plate III (SPPIII) test. This PIP test is a combination of both congenital and acquired red-green and blue-yellow test plates. Based on these scores, he failed this test OD, but passed OS. Furthermore, he failed only red-green CV test plates OD.
d. Farnsworth F2 plate: This single plate test was designed by the Navy to screen for tritan defects. It has some ability to also identify deutans. Mr. Frye failed the test with a response consistent with a deutan.
e. D-15: Mr. Frye failed the test with a response consistent with a color-weak deutan. He revealed a pattern OD with only one minor transposition and had two minor transpositions OS. There was no major crossing defects suggestive of a deuteranope.
f. The FM-100: Mr. Frye failed the FM-100 with scores of 188 OD and 200 OS. Axis analysis revealed a pattern consistent with a deutan.
g. Nagel Anomaloscope: His performance on the Nagel anomaloscope was consistent with a severe deuteranomaly.

h. Spectrum Colour Vision Meter (Anomaloscope): His blue-yellow metameric match on the Moreland equation was normal, however, his performance on the red-green Rayleigh equation was consistent with a severe deuteranomaly.
i. Farnsworth Lantern (FALANT): He passed the FALANT with 9/9 scores in each eye.
j. The remainder of his eye exam was essentially within normal limits, with no evidence of either lenticular or retinal changes that would suggest an acquired CV defect.

8. A review of his CV testing battery revealed that all test results were consistent with a congenital severe deuteranomaly. This was based on the scores, symmetry, and consistency of his performance on a variety of red-green CV tests and ultimately was confirmed by two different anomaloscopes, performed by two independent examiners. The Motrin dosage he was taking at the time was not believed to be contributing to his CV deficit.

9. Mr. Frye did however "pass" the FALANT lantern. When developed, the FALANT was designed to pass approximately 30% of CV defectives (mild deficiencies), which were thought to be compatible with existing aviation tasks at the time. However, multiple studies of the FALANT indicate that it can misclassify even the most severe types of red-green CV deficiencies, and "pass" them. Consequently, it was dropped in 1993 as a secondary USAF qualifying test used in any applicant who failed an initial primary PIP screener. In Mr. Frye's case, it also appears that the FALANT, did not correctly identify his CV deficiency throughout his entire Navy flying career, nor when administered here at the ACS. However, this notable test "pass" is inconsistent with all other CV testing we performed, but is consistent with a known testing inadequacy in the FALANT. Thus, we concluded that Mr. Frye has a severe congenital deuteranomaly and that this defect was not identified properly by the FALANT. This testing inconsistency with the FALANT has been previously documented in the literature.

10. When a variety of CV tests were evaluated by NATO-RTO and published in RTO Technical Report 16, "Operational Colour Vision in the Modern Aviation Environment" in 2001, the following observations were made.

a. "Even though lantern tests have been used for close to one hundred years, their validation and the availability of information on their reliability is almost nonexistent. The evaluation of most lantern tests and the failure rates associated with normals and CV defectives are either conflicting or simply insufficient. Test validation for this class of tests is both complicated and perhaps confusing. Cross validation of one lantern against another is confounded because of the differences in intensity, wavelength, target size and test distances."

b. "Validation of lantern tests by use of an anomaloscope has very rarely been attempted and cross correlation with plate tests has produced ambiguous results." In most cases, therefore, plate tests precede lantern tests with the notable exception of the US Navy where the Farnsworth lantern was used exclusively during this period of time.

11. Furthermore, we also believe that the type and degree of his congenital red-green defect could result in difficulties interpreting red-green and white signal lights that combine color and brightness, such as PAPIs and VASIs.

a. In 1973 Smith et al. applied a specialized technique to the evaluation of a group of deuteranomalous observers identified by the Nagel anomaloscope. Data relevant to this evaluation indicated that in the range from 510 to 660 nm, which is an area occupied by a considerable portion of the red system, under low light levels the hue was identified as "yellow" whereas when the light was brighter, it was identified as "white". Some observers did see a bit of red in the 660 nm range.

b. The PAPI light red filter produces "aviation red" as specified by MIL-C-25050. It's location in CIE space is at ca. 605 nm, which is in the middle of the red spectrum. Clearly, it is possible in this case, that the red lights of a PAPI could have been identified as "yellow" at lower light levels or "white" when the light was brighter.

12. However, his documented proficiency with over 8,000 flying hours suggests his performance using these devices could employ learned strategies, other than normal color discrimination, to "interpret" PAPIs. Our conclusions assume that the PAPI lights in operation at the time of the mishap were operating normally and were not providing errand information either in wavelength, brightness, or angle. The answer to this technical question, in addition to knowing details regarding the role of the other additional crewmembers, would be required before we could consider any further additional possibilities about the relationship and role of CV and other human or technical factors in this mishap.

[redacted]

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[redacted]

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