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SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT

By: Gregory Phillips

(14 pages)

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594
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SYSTEMS GROUP CHAIRMAN"S FACTUAL REPORT

A. ACCIDENT DCA-97-MA-058

Location: Agana, Guam
Date: August 6, 1997
Time: 0142 Guam Local Time
Aircraft: Boeing 747-3B5, HL-7468

B. SYSTEMS GROUP

Chairman: Gregory Phillips
National Transportation Safety Board
Washington, DC

Member: Ki Joo Song
Korean Air
Seoul, Korea

Member: Kevin Darcy
Boeing Commercial Airplane Group
Seattle, WA

C. SUMMARY

On August 6, 1997, at approximately 0142 Guam Local Time, a Boeing 747-300 (3B5B), operated by Korean Air Co. Ltd. as Korean Air flight 801, en route from Seoul, Korea (RKSS) to Agana Guam, crashed on approach to Runway 6 Left at the Guam International Airport (PGUM).

At the time of the accident, the glide slope associated with the instrument landing system (ILS) to Runway 6L was out of service and the crew was conducting a "localizer only" approach to the runway when the airplane contacted high terrain approximately 3 nautical miles southwest of the airport.

The 0132 reported weather at Guam International indicated that the wind was from 090º at 6 knots; visibility was 7 statute miles with showers and there was a scattered layer of clouds at 1,600 feet, a broken layer at 2,500 feet and an overcast cloud layer at 5,000 feet.

The flight was operated as a scheduled 14 Code of Federal Regulations (CFR) Part 129 passenger flight. There were two pilots, one flight engineer, one purser, nineteen flight attendants (includes six deadheading flight attendants), and 231 passengers on board the airplane at the time

of the accident. The airplane was destroyed by impact forces and a post-accident fire. Of the 254 occupants on board, 225 were killed; and 25 passengers and 4 flight attendants survived the accident with minor to serious injuries. However, during the 30 days following the accident, two passengers and one deadheading flight attendant succumbed to their injuries.

D. DETAILS OF THE INVESTIGATION

The systems group was formed at an organizational meeting on August 7, 1997. The group worked at the accident site on August 8-11, 1997. August 8 was dedicated to overall site examination and technical assistance to search and recovery personnel and to preserve evidence in the cockpit. August 9 was dedicated to the documentation of the first officer's instrument panel and center pedestal. After moving the cockpit wreckage, August 10 was dedicated to documentation of the captain's and flight engineer panels. On August 11, the group returned to the accident site and, with the assistance of a Korean Air B-747 captain and flight engineer, re-examined cockpit instrumentation.

The airplane impacted terrain on a hill along the approach path to runway 6L. The impact point was approximately 3.3 miles short of the runway along the extended centerline of runway 6L. The airplane's wreckage was oriented generally along a track of 063°.

The aircraft center section was consumed by fire. The cockpit was not burned but was destroyed by impact forces. The electronic equipment (EE) bay of the airplane was destroyed by the impact and several of the EE bay components were found along the wreckage debris path.

The empennage was impact-damaged but remained intact. The upper and lower rudder surfaces were displaced in different directions. The landing gear was extended.

The cockpit was found separated from the main fuselage and was broken open and inverted. There was no indication of fire in the cockpit area. Access to the instrument panels was gained by removing the captain's and first officer's (F/O) cockpit seats.

1.0 Cockpit Documentation

General

F/O control column could be moved fore and aft

F/O control wheel rotated left 3 units (ref. aileron trim scale- top of control wheel)

1.1 First Officer's Flight Panel

Glare Shield panel

EPR: Not selected (pressed)

MACH: Not selected (pressed)

SPEED: Selected (pressed)

VOR-UP/RT-DN/LT: Bent in-between

DME-STBY: Frequency not readable

RADIO/INS: RADIO selected

Electronic clock
Elapsed time control: RUN
GMT selector: RUN
Digital display: Blank

SAT Indicator
Yellow Bar: visible

Gross Weight Total/Fuel Weight Indicator
Gross weight: 4730
Total fuel: 0380

Attitude Direction Indicator
Face glass cracked
GYRO and RNWY flags in view
SLOW/FAST needle: SLOW (down)
Glide slope needle: 0.8 dot up
Roll: 0°
Pitch: 5° aircraft nose up

Horizontal Situation Indicator
Face glass cracked
Digital distance displays: Blank
Glide slope flag: visible
Glide slope Needle: 0.3 dot up
Course deviation needle: centered (aligned)
Course Bearing: 062°

Airspeed Indicator
Needle at 0
Barber pole: 375
Orange index at 134
White bugs at 130, 148, 210

Altimeter
Glass cracked
Left knob: bent
Right knob: missing
Standby flag: visible
Needle: Bent at 640
Digital altitude: 0600
QNH: 1016
Baro: 30.00

Radio Magnetic Indicator
ADF/VOR selector: #1VOR selected, #2 ADF selected
#1 Indicator: 110°
#2 Indicator: 155°

DME Indicator
DME 1 and DME 2 Digital displays: Blank

Radar Altimeter
- Flag: visible
- Needle: 10 feet
- Decision height: 305

TCAS Indicator
- Displays: Blank
- Flight Data Computer: B selected

Flight Control Position Indicator
- Right elevator: 2-3° up
- Left elevator: 20° up
- Upper rudder: 20° left (beyond maximum limit)
- Lower rudder: 7° left
- Left Aileron: 1° up
- Right Aileron: 15° up
- Left spoiler: almost 0°
- Right spoiler: almost 20°
- Flight Data/Autopilot/Autothrottle: all not selected (pressed)

1.2 Lower Pedestal

#1 VHF COM
- Left Frequency: 121.50
- Right Frequency: 128.95
- Selector Switch: OFF
- Transport: left frequency active

#2 VHF COM
- Left Frequency: 118.10
- Right Frequency: 121.90
- Selector Switch: ON
- Transport: switch missing

#3 VHF COM
- Left Frequency: 119.00
- Right Frequency: 131.90
- Selector Switch: ON
- Transport: Right frequency active

Aft Electronics Panel (Pedestal)
- SELCAL 1: HF 1 selected
- SELCAL 2: HF 2 selected
- Selector: Low marker

Weather Radar Panel
- Function Switch: Normal
- Radar number 2 selected
- Tilt: 4° up

TCAS

Range: 6 miles
TCAS Display Control: Right
Above-Normal-Below: Normal
Selector knob: RA/TA

Audio Selector panel

VHF 1 selected
ADF selected
Range selected
Amp 2 selected
Boom selected

ADF

Left Frequency: 385
Right Frequency: 320
Selector Switch: ADF
Tone Switch: OFF
Transport: left frequency active
Gain: 11 o'clock position

Horizontal stabilizer trim

Left side: 8.3 units a/c nose up
Right side: 8.2 units a/c nose up

Green band select switch: Mid-position and bent

Throttle levers

All 4 throttles: full forward
#3 and #4 levers bent towards the first officer

Fuel cutoff

#1: RICH
#2, #3, #4: IDLE

Speed Brake Handle: Down

Split STAB TRIM Handle

STAB: Loose
TRIM: Nose down

Rudder Trim: Full left rudder (probably pulled on impact)

Flap Lever

Flap lever 0° position
Lever jammed into #4 throttle lever
Latch pin out of race

1.3 Autopilot control panel

Autopilot Channel A, B, and C: OFF (Note: Switches require electrical power to remain engaged-loss of power will release solenoids and move switches to OFF)
Autothrottle: OFF
Course: 063 (both windows)
Heading: 049

Source Selector switch: cracked
Vertical speed select: -2500
Altitude select: 02500
Altitude select switch: OFF
Mode switch: OFF
Flight director switch right side: ON

1.4 Center pedestal instruments

EPR (all with flags visible)

Orange command bugs: #1-1.3, #2-1.0, #3-1.4, #4-1.4
Needles: #1-offscale, #2-off scale, #3-1.0, #4-off scale

N1 (all with flags visible)

All at 0

EGT (all with flags visible)

max. limit pointer 650-all gages
Needles: #1-off scale, #2-530, #3-440, #4-0

Fuel Flow (x1000, all with flags visible)

#1-5.0, #2-2.4, #3-1.0, #4-4.2

Flap position indicator

Glass cracked
Needle fully rotated

Landing gear selector handle

Gear down

1.5 Overhead panel

All Landing Light Switches: ON
Logo Light Switch: OFF
Flight control hydraulic power: switches missing
Auto-brake switch: OFF (switch jammed)
Anti-skid switch: closed
#1 engine fire handle: missing
#2, #3, #4 engine fire handles: normal
#1 engine ignition knob: missing
#2 engine ignition knob: mid position
#1, #2, #3 INS Mode selector switches: NAV
Compass Switch: SLAVE

1.6 HF Control Panel

#1 Switches: OFF, Freq. 8.703

squelch/volume: MAX

#2 Switches: OFF, Freq. 6.422

squelch/volume: MAX

1.7 Nacelle anti-icing panel

Switch off

1.8 Wing anti-icing panel

Switch: OFF
Probe heater: Left TAT: ON

Probe heater: Right TAT: ON
Window Heat: All switches down (ON)
Storm Switch: OFF
Main panel background light: 30° ON
Overhead Light: 20° ON

1.9 WSHLD panel

Windshield wiper switch-left: LOW
Windshield wiper switch-right: LOW

1.10 Captain's Flight Instrument Panel

Attitude Direction Indicator

GYRO, RNWY,G/S, COMPUTER Flags: visible
FAST/SLOW yellow bar: visible
Roll: 5° right wing down
Pitch: 2.5° A/C nose up
Glide slope needle: 0

Horizontal situation indicator

DME 1-DME 2 digital indicator: Blank
G/S, HDG flags: visible
Course deviation indicator: aligned
Course: 063
Course Bug: 063
Glide slope needle: 0.1 Dot below

Captain's Airspeed Indicator

Barber pole: 379
Needle: 0
White Bugs: 130
Orange Bug: 135
Yellow mach flag: visible

Captain's Altimeter (upper)

Digital altitude: 0550
Needle altitude: 560
Baro: 29.89
QNH: 1012

Captain's Altimeter (lower)

Digital altitude: 0100
Needle altitude: 110
Baro: 29.81
QNH: 1010

Radar Altimeter

Flag: visible
Needle: 10 feet
Decision height: 304

DME 1-DME 2 Digital display
Blank
Radio Magnetic Indicator
ADF/VOR selector: #1 VOR selected, #2 VOR selected
#1 Indicator: 075°
#2 Indicator: 223°
Aux. Fuel Switch: NORMAL
Flight Director: A channel
Flight Director Computer: A

1.11 Flight Engineer's Station
Aux. engine panel
N2: #1-0, #2-73, #3-35, #4-0
all yellow flags visible
all four red needles at red max.
Oil Qty: all off-scale
Oil Temp: all -40
Oil Pressure: #1-over 100, #2-53, #3-22, #4-22
Cabin pressurization control panel
Cabin altimeter altitude: 0
Cabin vertical speed: 0 (Baro: 29.86)
Cabin Pressure controller mode: AUTO
Cabin Pressure Rate: DECREASE
Compartment temps: Bottom scale (60°)
Duct temps: Bottom scale
Fuel Panel
Gross weight: 4700
Total fuel: 0385
Fuel used: 20180, 21200, 20270, 20210
#1 reserve 00.1, #2 reserve 00.1, #3 reserve 00.1, #4 reserve 00.1
Main's #1-09.5, #2-08.7, #3-08.8, #4-09.7
Center wing tank: 01
Scavenge pump: OFF
Fuel Heat: OFF, AUTO, OFF, Broken
Spar valve: open, open, open. Open
Boost pumps: Both ON (all 4 tanks)
CTR Boost (OVRD/JETT Pumps): Both OFF
Cross-feed: #1-closed, #2-open, #3-closed, #4-closed
Reserve valve:#1 open, #4 closed and damaged
#2 Reserve transfer valve: closed, guard damaged
#3 Reserve transfer valve: closed, guard damaged
TAT: -15.5°C, OFF flag visible

The airplane's GPWS computer, and VHF control panels (Captain's and F/O's) were removed from the accident site for additional testing

Additional notes

The systems group found aircraft dispatch, maintenance, and navigation documents in the cockpit wreckage. The aircraft maintenance log indicated no entries for the accident flight. These items were copied and turned over to the maintenance records and operations group.

All flight control surfaces appeared to be attached to the airplane. The elevators and rudders appeared normal other than impact-related damage. The ailerons, spoilers, leading and trailing edge lift devices were damaged by post-impact fire. Documentation of these items are contained in the Structures Group Chairman's factual report.

Measurement of the horizontal stabilizer trim jack screw indicated that the horizontal stabilizer was set at 7.5 units.

A review of Korean Air maintenance records indicated that the Rockwell Collins model 51RV-5B navigation units were installed in all 3 positions in the airplane. During discussions with the systems group, Boeing asked Korean Air for documentation of the installation certification basis for the 51RV-5B units. Korean Air stated that they would provide details of the certification approvals for the installation on the accident aircraft. This information will be added to the accident data files when if becomes available.

There were no deferred or open maintenance action items related to the airplane's instrument landing system or navigation equipment at the time of the accident. The following information was obtained regarding the navigation units.

installed position	part number	serial	installation date
#1	822-0761-001	1668	24Nov96
mod status	1,2,3,4,5,6,8,9,10,11,13,14,16,18,19,20,23,25,33,L		
#2	822-0761-005	7548	01Feb97
mod status	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,25,33,L		
#3	822-0761-001	2372	17May97
mod status	1,2,3,4,5,6,8,9,10,11,13,14,18,19,20,23,25,33,L		

2.0 PHASE II: EXAMINATION OF VHF CONTROL PANELS AND GPWS COMPUTER

Chairman: Gregory Phillips
National Transportation Safety Board
Washington, DC

Member: K. J. Song
Korean Air
Seoul, Korea

Observers:	H. M. Kwon and Y.W. Chung Korean Air Seoul, Korea
Observers:	B.T. Yoo and D. Y. Yoon Ministry Of Construction and Transport Seoul, Korea
Observer:	David Pickering (Pacific Aero Tech only) Pacific Aero Tech Kent, WA
Member:	Pamela Rosnik (delegated by Kevin Darcy) Boeing Commercial Airplane Group Seattle, WA
Observer:	Jessie Turner (Pacific Aero Tech only) Boeing Commercial Airplane Group Seattle, WA
Observer:	Matt Larson (AlliedSignal only) Boeing Commercial Airplane Group Seattle, WA
Observer:	Larry Epstein (AlliedSignal only) AlliedSignal Redmond, WA

2.1 Pacific Aero Tech-VHF Control Panel Examinations

On October 2, 1997, the team met to examine the captain's and first officer's VHF Control Panels removed from the accident wreckage in an effort to determine the frequency selected on each unit. The examinations were conducted at Pacific Aero Tech Inc, Kent, Washington, an FAA authorized repair station for the control panel. Gables (the control panel manufacturer) coordinated Pacific Aero Tech's support.

It was determined that the captain's selector was tuned to 110.30 MHz (the Agana, Guam ILS frequency). The first officer's selector was tuned to 116.60 MHz. The Captain's control panel was damaged by impact forces and the selected frequency was locked into position by the impact and could not be changed by turning the frequency selector knob. The first officer's control panel selector knobs turned easily and were subject to change as a result of post-impact cockpit movements.

2.1.1 First Officer's VHF Control Panel (p/n. G-5699A, s/n 26)

The control panel case was removed to examine the interior for damage. No remarkable damage other than minor corrosion on interior structural components was noted.

A test "break-out" box was connected to the unit to read the "2 of 5" code table values. This box allowed determination of the frequency selected by comparing lights on the test box to a look-up table on the Gables Engineering, D-26, 210A-Model G-5699A VHF Nav Control Panel Outline and Wiring Diagram, engineering drawing. This test indicated that the frequency selected on the s/n 26 control panel was 116.60 MHz.

2.1.2. Captain's VHF Control Panel (p/n. G-5699A, s/n 17)

The unit was damaged by impact forces. The case was dented into the unit. The case was removed and the internal mechanisms were examined and found damaged by impact forces. The impact damage prevented turning the frequency selector switches. The frequency display module was removed to gain access to the selector switches.

The selected frequency was determined by comparing the position of: the stop collar pin, shaft flat, the internal switch rotor contactors, and the MHz and Fractional switch selectors with the s/n 26 unit and the engineering drawings. This comparison resulted in the determination that the unit was tuned to 110.30 MHz.

2.2 AlliedSignal Ground Proximity Warning System (GPWS) warning computer tests

On October 3, 1997, the examination team met at AlliedSignal facilities in Redmond, Washington. The purpose of the examination was to read the non-volatile memory from the computer to document any warnings that had been generated by the computer. Although the computer was slightly damaged by the accident impact, the 64-flight history was successfully read out and an automated test procedure was accomplished.

The GPWS computer (p/n 965-0876-030-B05-B08, s/n 1949, mfgr date 9318,) was taken to the test bench and connected to the test controller. Prior to testing, the side panels were opened and separated from the circuit boards. There was minor impact damaged but the internal components appeared to be functional. The first attempt to initialize and begin the tests failed. The electrical connector to the test system was removed and reconnected. The two main circuit boards were moved and the ribbon connectors were examined. On the second attempt, the unit successfully began the test program.

The first test performed was a query of the 64-flight history recorded in the unit's non-volatile memory. The following were the only events noted:

Sink rate warning-Flight 1*
Glideslope caution-Flights 15, 47
Bank angle warning-Flight 1*
Ground History: Pitch #1 Fault, Roll #1 Fault

Note:
*Flight 1 is the accident flight. There were no fault messages for any LRU and no Glideslope warning for flight 1.

2.2.1 GPWS Product Specification Definitions for SINK RATE and BANK ANGLE Warnings

The AlliedSignal Product Specification for the Commercial MKVII Warning Computer, drawing 965-0876-602, revision T, was used for definitions of the flight history warnings.

The SINK RATE alerts (Mode 1) are generated based on altitude rate and radio altitude. The alerts and warnings are active for all phases of flight whenever the aircraft is between 10 and 2,450 feet AGL. The SINK RATE warning becomes a PULL UP warning when the rate of descent increases and/or radio altitude decreases beyond the SINK RATE warning envelope. The mode envelope for the warnings is described on sheet 27 of the reference document.

The BANK ANGLE alerts (Mode 6) are generated based on aircraft roll angle and radio altitude; neither roll rate nor descent rate affect the warning curve.

The GLIDESLOPE (Mode 5) alert provides an alert when deviation below glideslope becomes excessive on front-course ILS approaches. Mode 5 alerts are based on radio altitude and glideslope deviation. Mode 5 alerts provide different alert volumes and variable delay between messages depending on the severity of the glideslope deviation.

The Mode 5 alerts are provided when the following conditions are met:

- a valid glide slope signal is selected on the connected ILS system
- the MK VII is in the approach mode or flaps are in the landing range
- Glideslope has not been canceled with the Glideslope alert cancel button
- gear are down
- radio altitude is greater than 30 feet
- Mode 5 is not inhibited by a back course select or other inhibit signal

The Ground History (added with the B05 program module) stores any faults that are present whenever the MKVII self test is performed on the ground. The fault messages are retained in memory until the aircraft goes through an air-to-ground transition. Such a transition is defined by airspeed $\leq$ 80 kts. And radio altitude $\leq$ 5 feet. There is a one second delay after these conditions are met before Ground History is erased.

The two faults that appear in the Ground History readout, Pitch #1 Fault and Roll #1 Fault, indicate that this data from the inertial reference system was not valid when the MKVII self test was performed prior to takeoff.

Following the flight history report, an automated test was performed to verify the unit's operational characteristics. All unit failures during the automated test program were attributed to impact-related damage. Excerpts of the automated test including a test failure log are attached to this report.

3.0 Systems Group Meeting Action Items from October 2 and 3, 1997 and Boeing responses

Following a discussion among the Systems group members relative to glideslope operation on the Boeing 747-300 aircraft, the following action items were assigned:

1. Boeing will verify that cruise mode will be maintained if no valid glideslope signal is received. Boeing response B-B600-16277-ASI, October 23, 1997, states:

> Without a glideslope signal, no pitchover will occur and the aircraft will remain in cruise mode.
>
> When the ILS Mode is selected and the glideslope beam error is greater than 30 microamps (1/3 Dot), the glideslope arm is annunciated. The pitch control remains in the Pitch Computer (Cruise Computer) and operates in any of the selectable modes; Altitude Hold, Altitude Select, IAS Hold, or Vertical Speed. When the glideslope beam error decreases to 30 microamps, the Vertical Beam Sensor (VBS) trips and switches the Landing Computer (LRCU) to take over pitch axis elevator control. Without the glideslope signal, the switch to the LRCU will not occur and therefore, no pitchover command will be given.

2. Boeing will verify autopilot logic for flag times for engage and disengage of autopilot. Boeing response B-B600-16277-ASI, states:

> The glideslope valid signal is used to arm the glideslope engage logic and the VBS logic. The valid glideslope signal has a 10-second delay built into the logic which must initially be satisfied to get the Glideslope Engage Mode ("G/S ENG" green annunciation also appears on the Flight Mode Annunciators). Once the VBS trips and the glideslope superflag is good, then both the glideslope receiver "valid" and the VBS signal are latched to the "true" state. With a single channel autopilot and ILS engaged, a failed glideslope signal will be annunciated along with a steady red autopilot warning light. The pilot would disengage manually on seeing the red autopilot warning light.

3. Boeing will verify that warning flags on both ADI and HSI should come on when no valid G/S signal or false signal is received. Boeing response B-B600-16277-ASI, states:

> The ADI and HSI display the flags per the output of the VHF Nav Receivers. Without a glideslope radio signal present from the ground, the internal monitoring function will set the superflag signal to "invalid" and the flags will be displayed.

In response to a discussion about the Boeing 747 automatic go-around mode during a Systems Group meeting in Seattle on 11 February, the following information regarding go-around and autothrottle response was provided by Boeing

The go-around mode is initiated by depressing the #2 or #3 palm switches located on the throttle levers. The accident airplane was equipped with a Full Flight Regime Autothrottle with an active go-around mode. This mode is armed via the "GA" arm signal from the autopilot whenever the AP or FD is "On". Otherwise, the selection of landing flaps 25-30 degrees will arm the autothrottle if the AP or FD are not engaged.

The autopilot only ARMS the go-around mode for the following:

1) ILS or LAND selected on the MSP

and

2) the Vertical Beam Sensor tripped (needs a valid glideslope signal with a deviation signal of less than 30 micro amps)

and

3) the airplane is in the air.

Gregory Phillips
Systems Group Chairman

2/27/98