National Transportation Safety Board

Improving Safety through Accident Investigation

Robert L. Sumwalt

NTSB is an independent federal agency, charged by Congress to investigate transportation accidents, determine probable cause, and issue safety recommendations.

NTSB

The Board

Earl Weener

Bella Dinh-Zarr
Vice Chairman

Chris Hart
Chairman

Robert Sumwalt

NTSB

Our mission:

Prevent Accidents

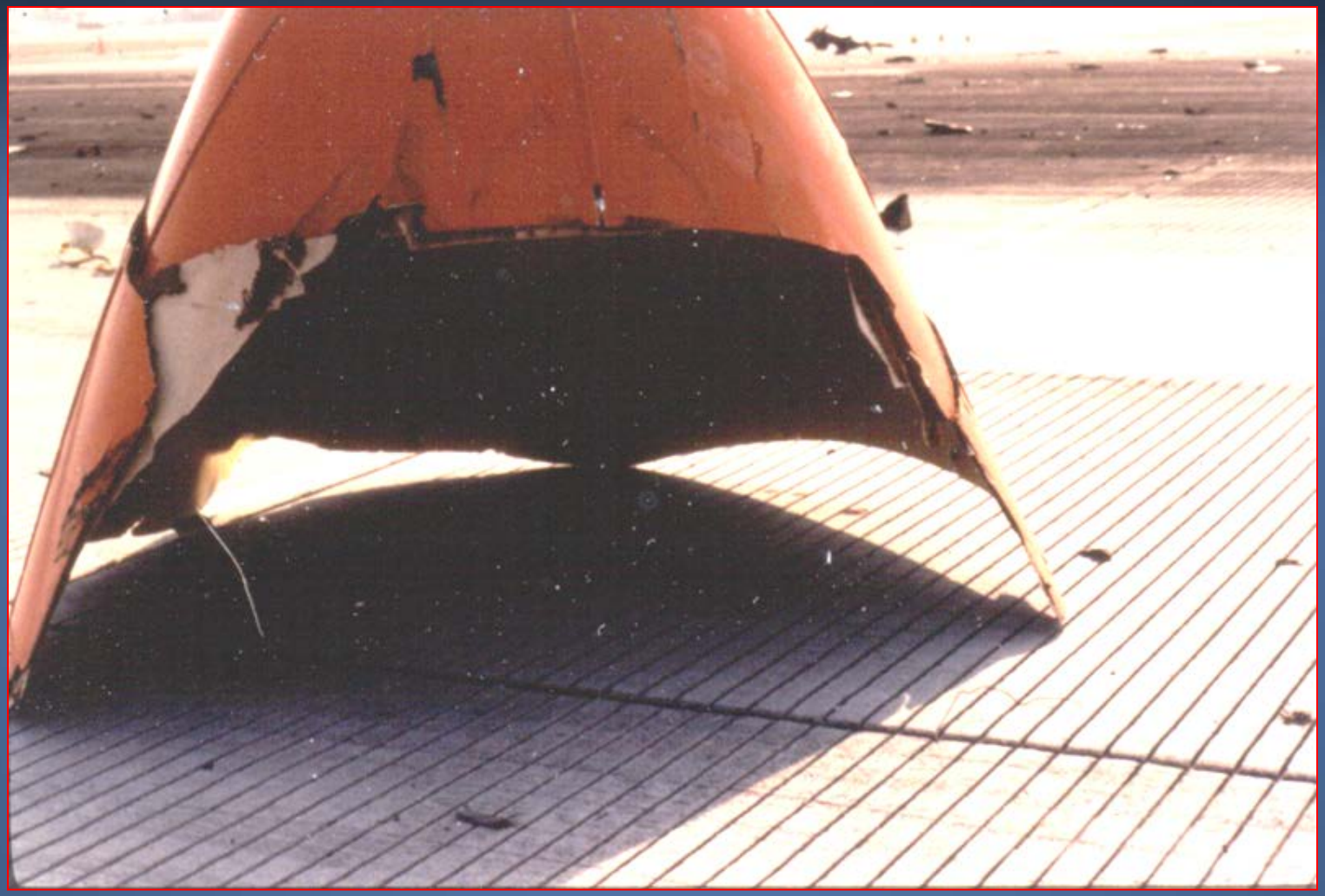
Reduce Injuries

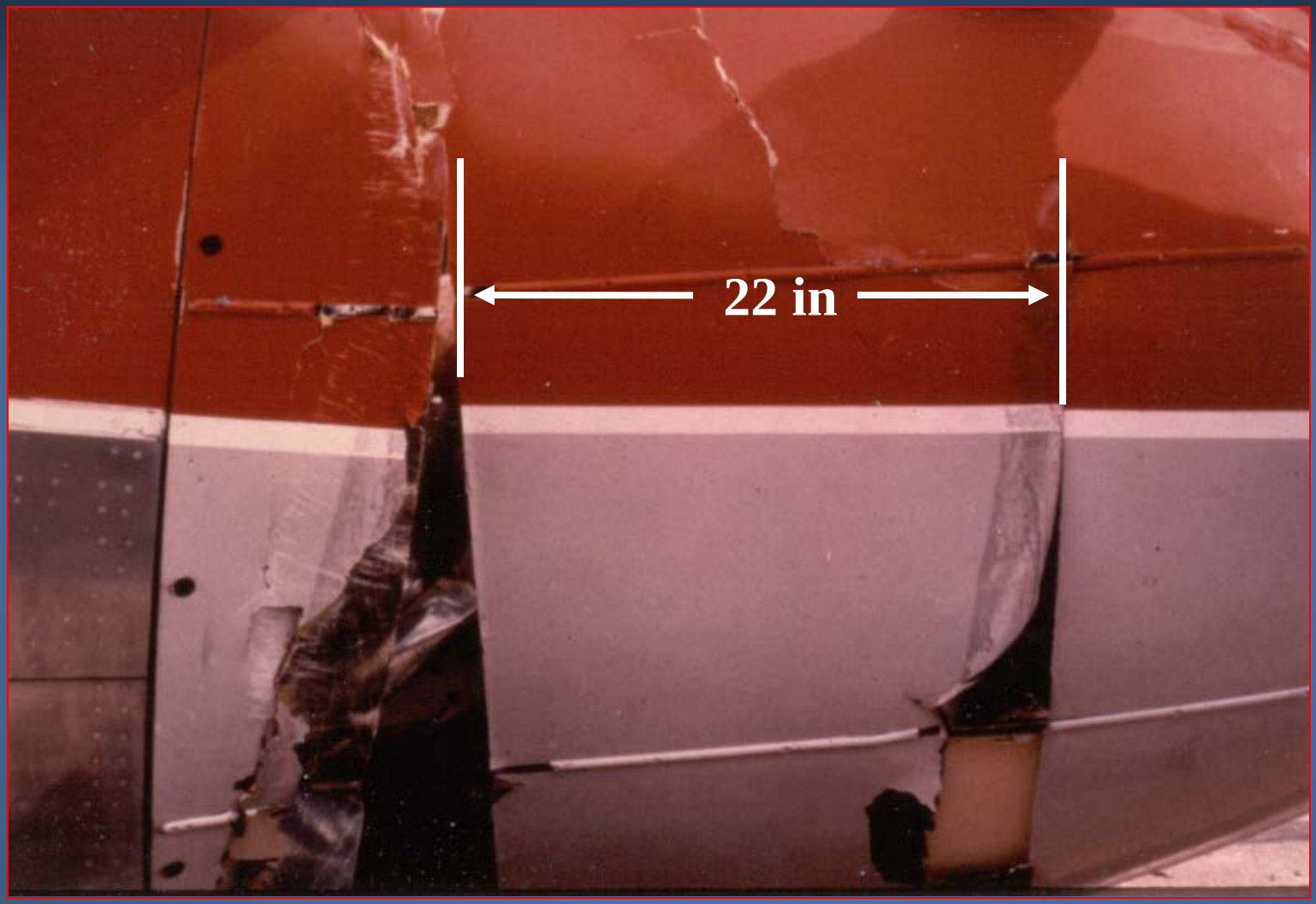
Save Lives

Accident Investigation Technique

PROP SLASH MARKS

SKYWEST
1171




22 in

SPEED = DISTANCE / TIME

DISTANCE = _____ in / 12 = _____ ft

PROP SPEED = _____ rpm / 60 = _____ rps

BLADES/SEC = # OF BLADES X PROPSPEED

= _____ BLADES X _____ rps = _____ bps

TIME = 1 / bps = 1 / _____ bps = _____ sec/blade

SPEED = DISTANCE / TIME = _____ ft / _____ sec

SPEED = _____ fps = _____ knots

SPEED = DISTANCE / TIME

DISTANCE = 22 in / 12 = 1.833 ft

PROP SPEED = 1543 rpm / 60 = 25.7 rps

BLADES/SEC = # OF BLADES X PROPSPEED

= 4 BLADES X 25.7 rps = 102.9 bps

TIME = 1 / bps = 1 / 102.9 bps = .00972 sec/blade

SPEED = DISTANCE / TIME = 1.833 ft / .00972 sec

SPEED = 189 fps = 112 knots

The Flight Data Recorder showed 118 knots

We calculated 112 knots.

Why is there a difference?

118 knot AIRSPEED
Minus
6 knot wind
Equals
112 knots GROUND SPEED

Accident Investigation Technique

PROP WITNESS MARKS

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Accident Investigation Technique

LIGHT BULB FILAMENT ANALYSIS

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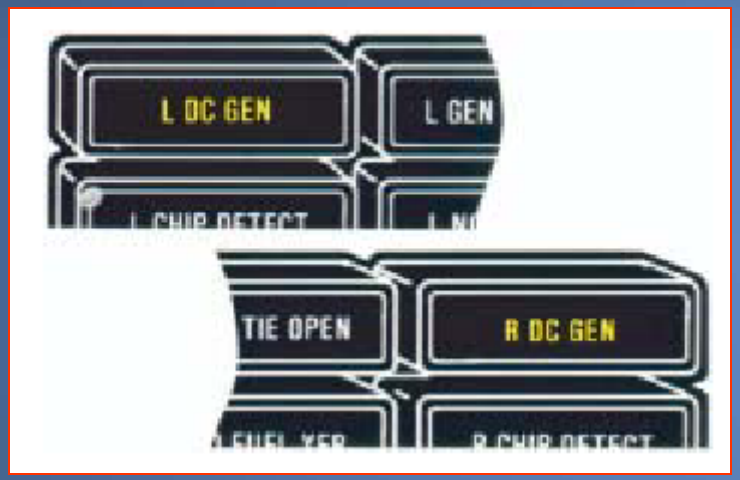
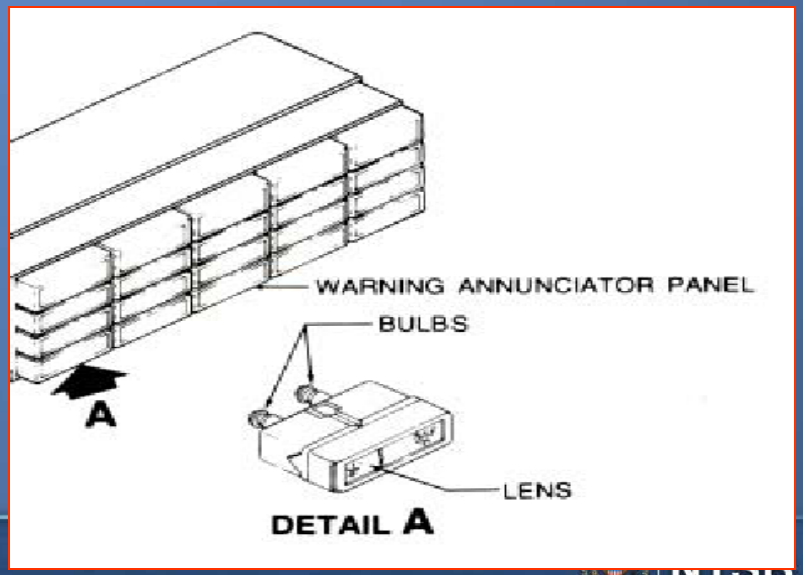
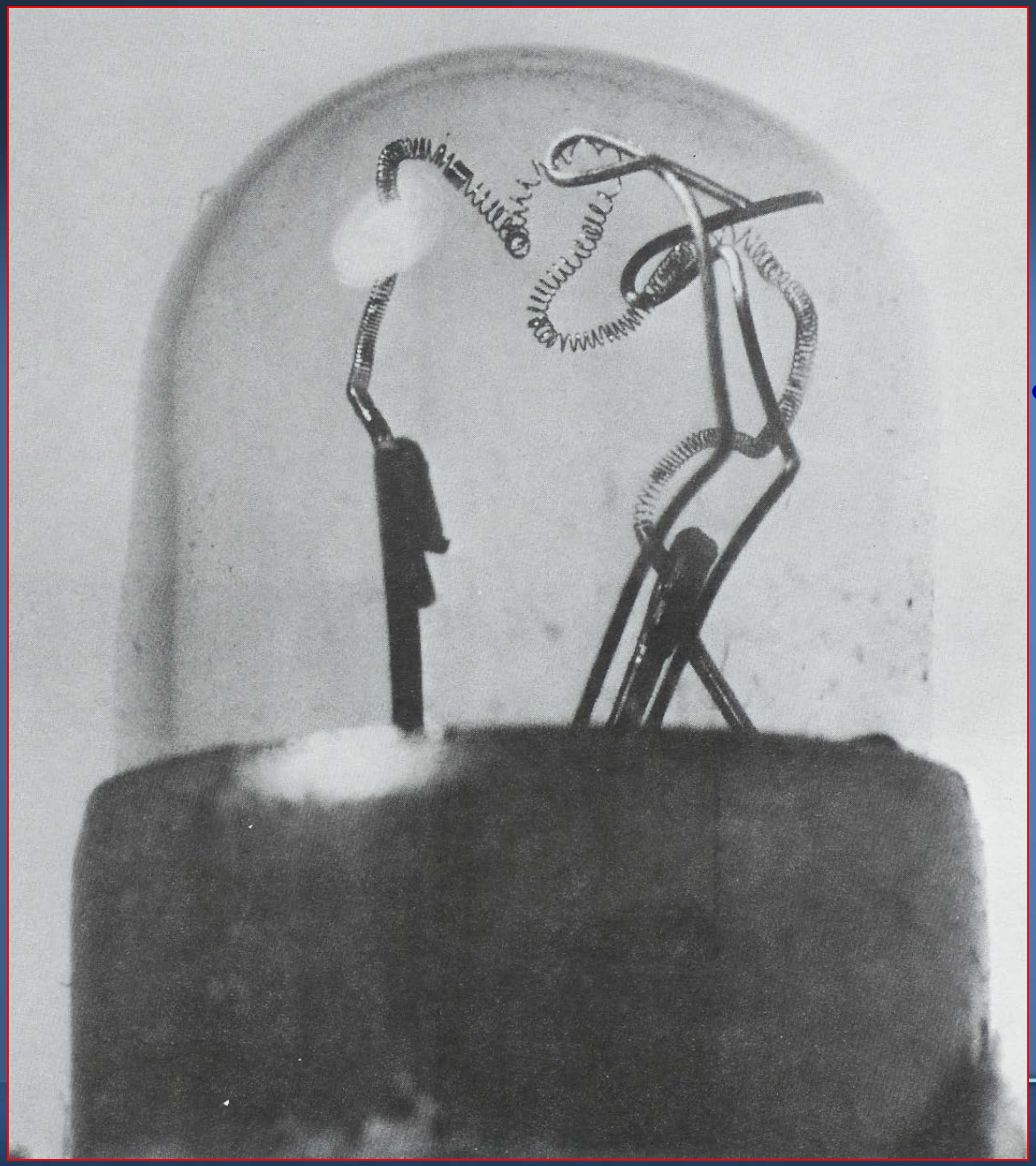
Light Bulb Filaments







- Was this light illuminated or extinguished at impact?

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Breaking News: A plane has crashed.

NTSB Response Operations Center

Anatomy of an accident investigation

NOTIFICATION + 2 HOURS

The Launch

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EXIT
NTSB
NTSB
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NATIONAL TRANSPORTATION SAFETY BOARD
DURABLE

Arrival on Scene

Boots on the Ground

National Transportation Safety Board

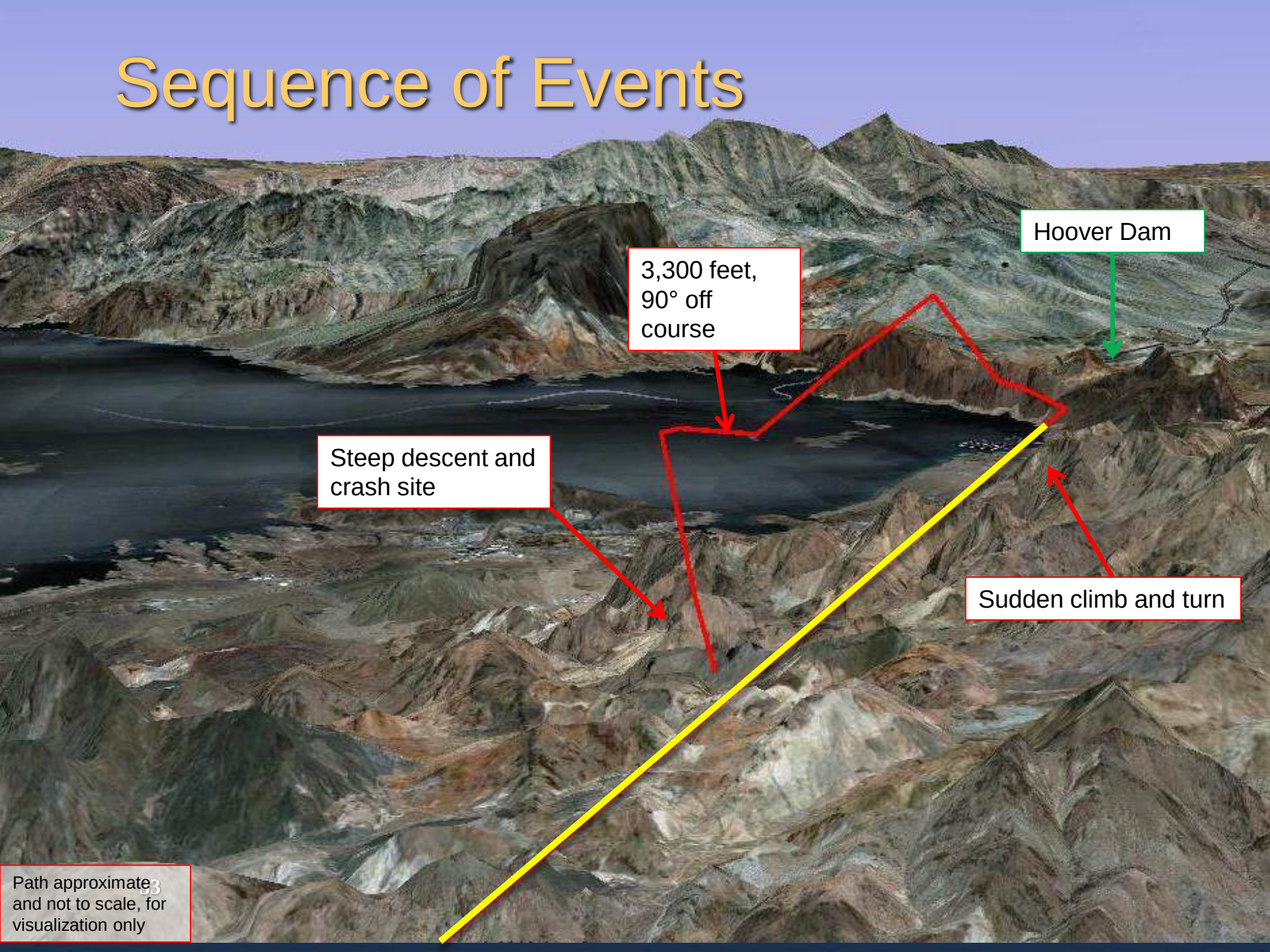
Loss of Control Eurocopter AS350

Las Vegas, Nevada
December 7, 2011

Initial Information

- Sightseeing tour from Las Vegas to Hoover Dam
- Normal departure – visual flight rules
- Calm wind, good visibility
- Standardized tour route

Sequence of Events

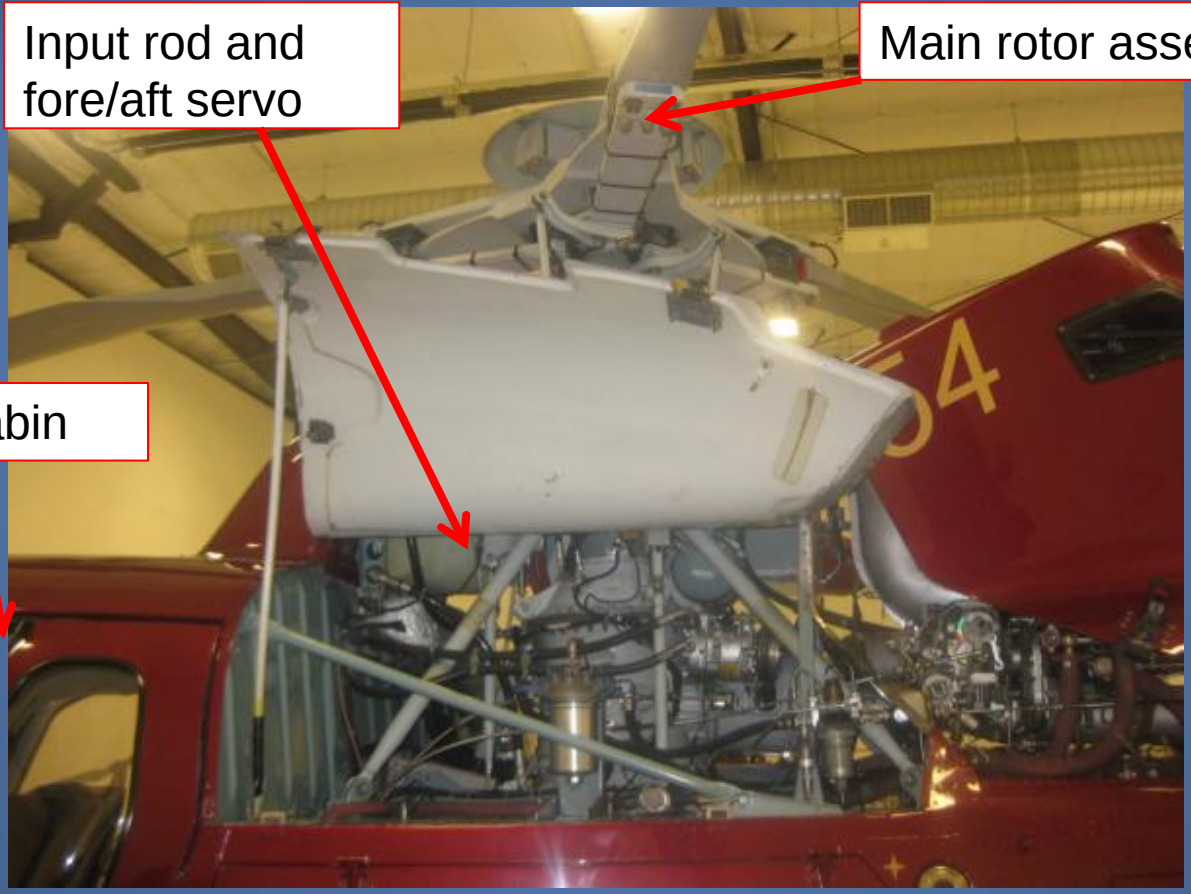


Fuselage
and engine

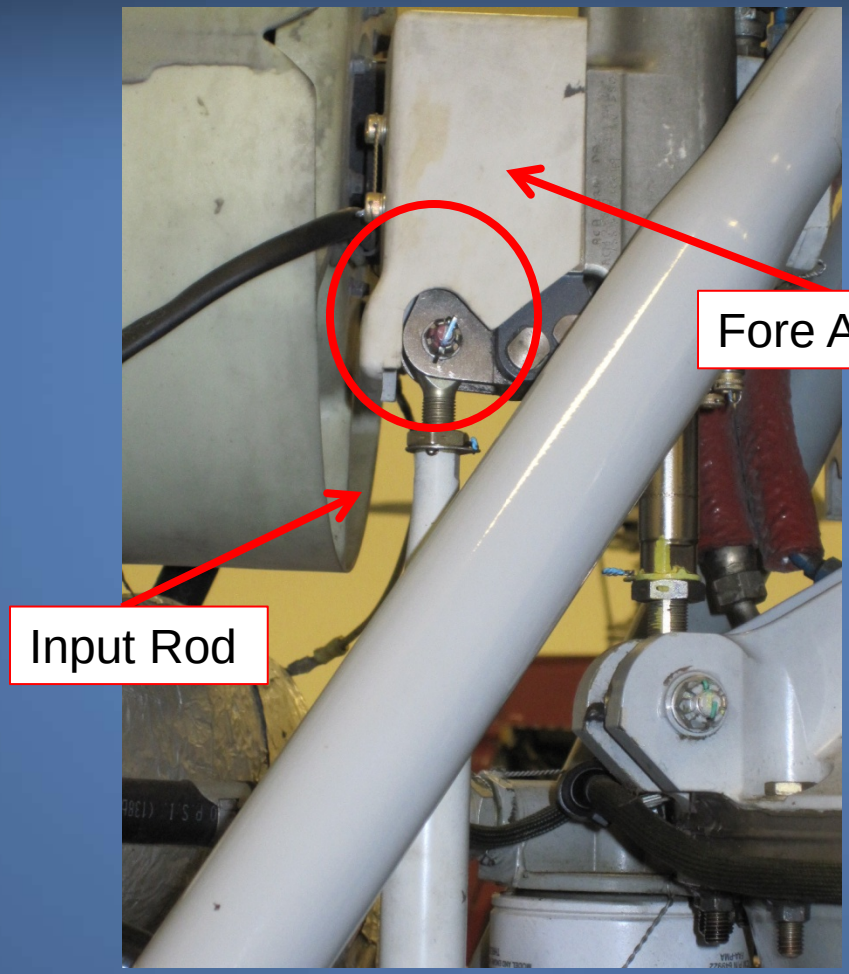
Events prior to accident

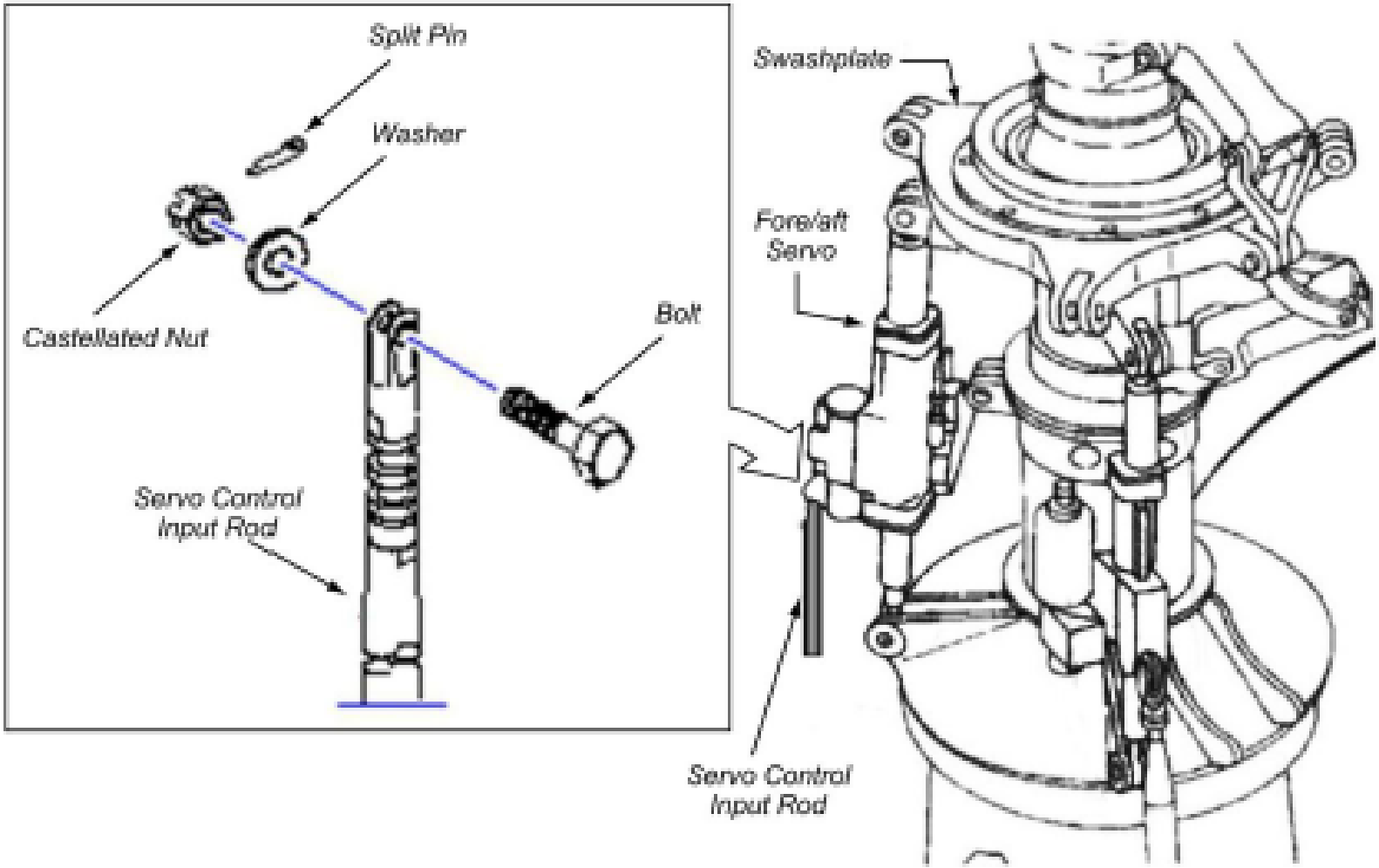
- 100-hour maintenance inspection conducted the day prior
- Fore/aft servo replaced
- Check flight flown
- 2 tour flights flown
- Accident occurred on
  - Third tour flight
  - 3.5 flight hours after maintenance

View of Helicopter Components



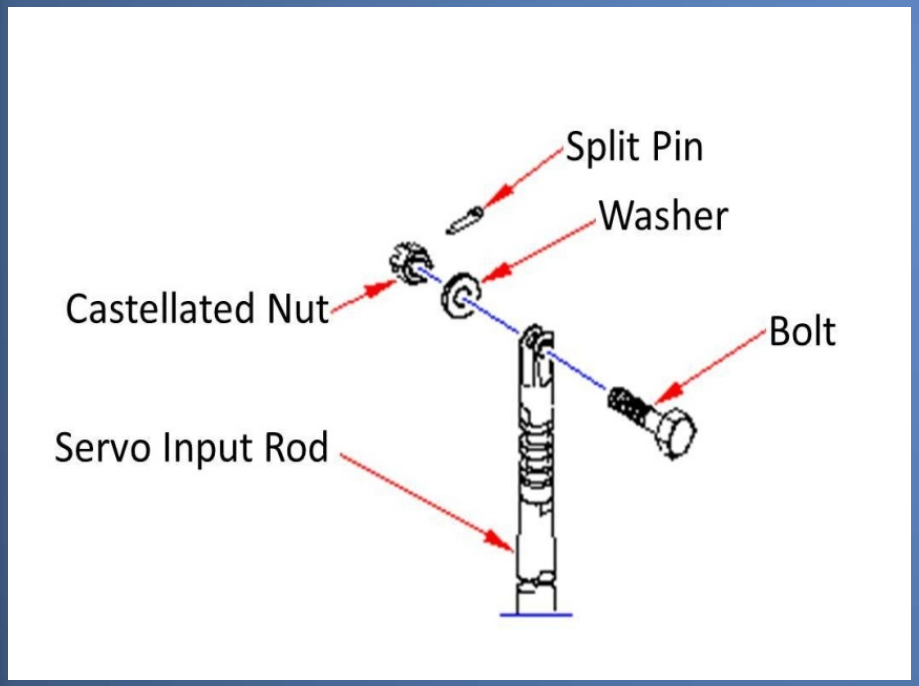
Installed Connection



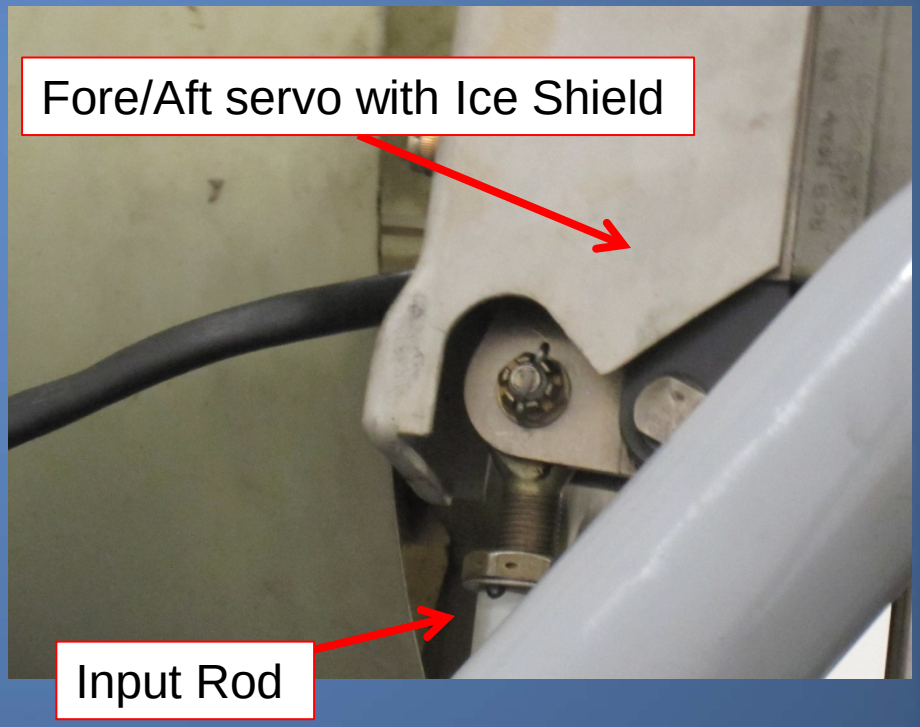

Split Pin
Washer
Castellated Nut
Bolt
Servo Control
Input Rod
Swashplate
Fore/aft
Servo
Servo Control
Input Rod

Hardware

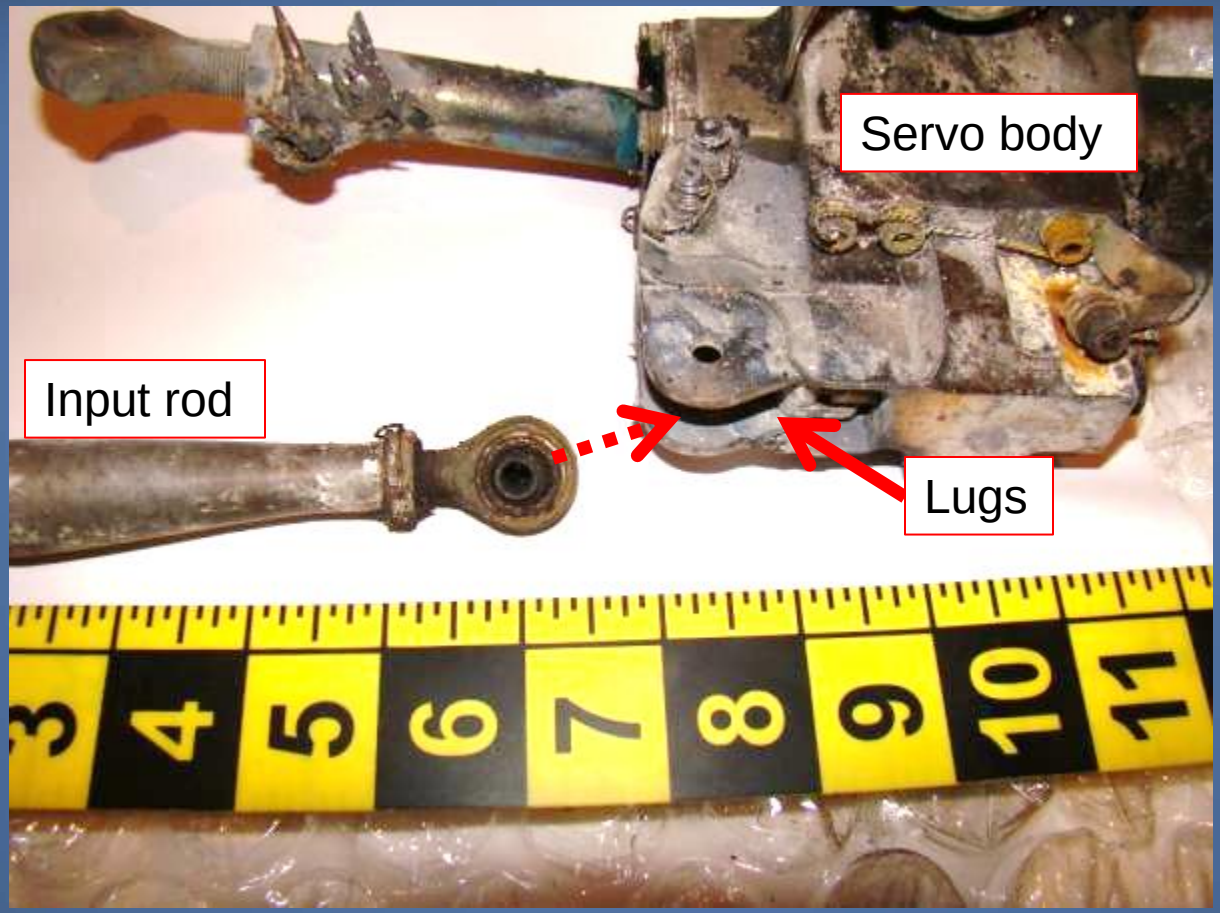
Input rod hardware



Hardware installed



Input Rod and Servo



Maintenance Performed day prior to accident

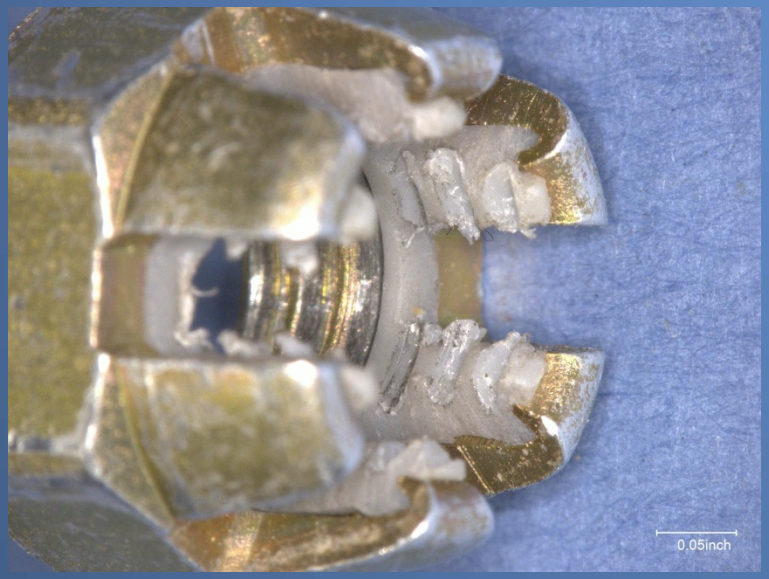
- 100-hour inspection
- Replacement of the following:
  - Engine
  - Fore/aft and tail rotor servos

Fore/Aft Servo Installation

- Fore/aft servo installation procedures:
  - Assess hardware
  - Connect servo to input rod
  - Torque nut
  - Install split pin
- Inspect installation

Self-Locking Nut

Acceptable Nut



Degraded Nut

Hardware Reuse

- Post accident inspection of 13 Sundance helicopters - half of nuts did not meet below requirements

Manufacturer's guidance: "If a nut can be easily tightened, it is to be discarded"

FAA guidance: "DO NOT reuse a fiber or nylon lock nut if the nut cannot meet the minimum prevailing torque values"

NTSB Finding

- The fore/aft servo bolt most likely disengaged because:
  - the split pin was installed improperly or it was not installed, and
  - a self-locking nut that either was degraded or not torqued was used
- This allowed the nut to unthread and separate from the bolt.

NTSB Finding

"The mechanic, inspector, and check pilot each had at least one opportunity to observe the fore/aft servo self-locking nut and split pin; however, they did not note that the split pin was installed improperly or not present."

Maintenance Personnel Fatigue

- The mechanic
  - Recent sleep and wake activity
  - Shift change
  - Inadequate sleep

Maintenance Personnel Fatigue

- The inspector
  - Recent sleep and wake activity
  - Shift change
  - Long duty day

Maintenance Personnel Fatigue

Personnel	Normal Shift	Shift Originally Scheduled for December 6	Actual Schedule on December 6
Mechanic	Noon to 11:00 pm	Off duty	5:50 am to 6:46 pm
Inspector	Noon to 11:00 pm	Off duty	5:31 am to 6:55 pm

Fatigue Affects on Performance

- 2 hour sleep debt can produce performance decrements comparable to those produced by BAC of 0.045.
- 4 hour sleep debt can produce performance decrements comparable to BAC of 0.095.

Sleep loss decreases performance

- 2 hours sleep loss
  - » Productivity decreases by 17 percent
- 4 hours sleep loss
  - » Productivity decreases by 43 percent

- Source: Mark Rosekind, Ph.D.

According to experts…

"When you lose sleep or disrupt your sleep clock, every aspect of your capability as a human being is impaired."

- Mark Rosekind, Ph.D.

Rosekind says that even moderate sleep loss can result in decreases in:

- **Memory** (up to 20%)
- **Vigilance** (75%)
- **Communication skills** (30%)
- **Reaction times** (25%)
- **Judgment-making skills** (50%)

Board Meeting

NTSB

Probable Cause

Sundance Helicopters' inadequate maintenance of the helicopter, including:

(1) the improper reuse of a degraded self-locking nut

(2) the improper or lack of installation of a split pin

(3) inadequate post-maintenance inspections, which resulted in the in-flight separation of the servo control input rod from the fore/aft servo and rendered the helicopter uncontrollable.

Probable cause (continued)

- Contributing to the improper or lack of installation of the split pin was the mechanic's fatigue and the lack of clearly delineated maintenance task steps to follow.
- Contributing to the inadequate post-maintenance inspection was the inspector's fatigue and the lack of clearly delineated inspection steps to follow.

Recommendation

Establish duty-time regulations for maintenance personnel which take into consideration factors such as:

- start time
- workload
- shift changes
- circadian rhythms
- other factors shown by recent research and scientific evidence

Recommendation

Encourage operators and manufacturers to develop and implement best practices for conducting maintenance including, but not limited to the use of work cards for maintenance tasks

- especially those involving safety-critical functions, that promote the recording and verification of delineated steps in the task that, if improperly completed, could lead to a loss of control.

100-Hour Inspection Paperwork

MAKE	Eurocopter	DISCREPANCY LIST	DATE	12/06/11
MODEL	AS350B2	SUNDANCE HELICOPTERS	AF TT	26216.5
S/N	2300	5596 Haven Street	ENG TT	7400.0
REG.	N37SH	Las Vegas, Nevada 89119	PAGE	4 of 10

DISCREPANCY	CORRECTIVE ACTION
No. 15 M/R F/A SERVO PN AC67246 SN RX 187 DUE O/H	RMVD M/R F/A SERVO SN RX 187 TSO: 1959.5 TSN: 14202.3. INST'D O/H UNIT SAME PN SN BX 264 TSO: 0.0 TSN: 21150.9. ALSO REPLACED ALL ORINGS PN 81810-110-24B7 PO 9048. REF AS 350 M/M CH 67 sign off
Name [redacted] Date 12-6-11	Signature [redacted] Cert. No. [redacted] Date 12-6-11 Insp [redacted]
No. 15 M/R F/A SERVO PN AC67246 SN RX 187 DUE O/H	RMVD M/R F/A SERVO SN RX 187 TSO: 1959.5 TSN: 14202.3. INST'D O/H UNIT SAME PN SN BX 264 TSO: 0.0 TSN: 21150.9. ALSO REPLACED ALL ORINGS PN 81810-110-24B7 PO 9048. REF AS 350 M/M CH 67
Name [redacted] Date 12-6-11	Signature [redacted] Cert. No. [redacted] Date 12-6-11 Insp [redacted]
No. 16 T/R SERVO PN AC67032 SN FE 212 DUE O/H	RMVD T/R SERVO SN FE 212 TSO: 1959.5 TSN: 12328.4. INST'D O/H UNIT SAME PN SN DK287 TSO: 0.0 TSN: UNK. ALSO REPLACED ALL ORINGS PN 81810-110-24B7 PO 9048. REF AS 350 M/M CH 67
Name [redacted] Date 12-6-11	Signature [redacted] Cert. No. [redacted] Date 12-6-11 Insp [redacted]
No. 17 Remove Arriel 1D1 Engine S/N *9399* Rental Yes [ ] No [XX]	Removed Arriel 1D1 Engine S/N *9399* Engine TT. *11926.1* Total Ng *13996.03*, Total Np *15499*. Reference AS350B2 AMM Chapter 71-11-00 Para 4-1. Engine tagged appropriately.
Name [redacted] Date 12-6-11	Signature [redacted] Cert. No. [redacted] Date 12-6-11 Insp [redacted]
No. 18 Install Arriel 1D1 Engine S/N *9043* Engine T.T. *7400.0* Total Ng *9667.2* Total Np *7845.3* Rental [XX] Yes [ ] No	Installed serviceable Arriel 1D1 Engine S/N *9043* Reference AS350B2 AMM Chapter 71-11-00 Para 4-2.
Name [redacted] Date 12-6-11	Signature [redacted] Cert. No. [redacted] Date 12-6-11 Insp [redacted]
No. 19 Clean the Air Duct.	Cleaned Air Duct ref. Arriel 1D1 MM 71-01-03-110-801-A01.
Name [redacted] Date 12-6-11	Signature [redacted] Cert. No. [redacted] Date 12-6-11 Insp [redacted]

SDM-002 Revision: Original

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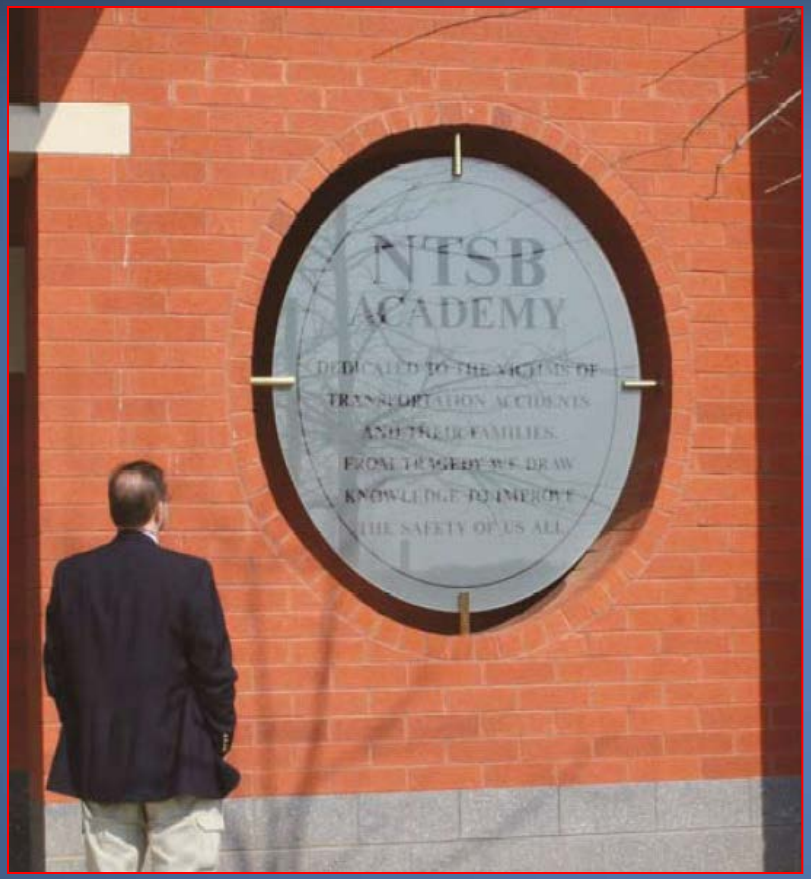
Work Cards With Delineated Steps

Sample work card

	DESCRIPTION	MECH	INSP
D.	Check trunnion bearings and drag brace bearing for proper installation and freedom of movement.		Insp. Y
3.	INSTALL NOSE LANDING GEAR - REFERENCE AMM		
A.	Support gear and jack with axle jack to insert trunnion pins in respective spherical bearings (13) on each side of the nose gear wheel well.	Mech. X	Insp. Y
B.	Jack gear to proper height and tap trunnion pin into place in each trunnion and trunnion support spherical bearing (13) then remove axle jack. **NOTE:** **NOSE GEAR MUST BE LIFTED INTO POSITION WITH GEAR TRUNNION AXIS PARALLEL TO TRUNNION BEARING AXIS.**	Mech. X	Insp. Y
C.	Ascertain that the trunnion pin lockpin holes are in alignment with mating holes in trunnion pin lockpins.	Mech. X	Insp. Y



"From tragedy we draw knowledge to improve the safety of us all."

National Transportation Safety Board