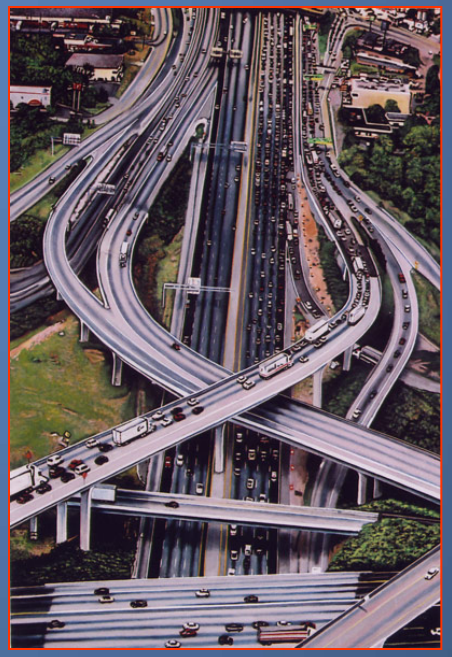
National Transportation Safety Board

The role of maintenance and inspection in accident prevention

Robert L. Sumwalt
NTSB Board Member

Inspection Authorization Renewal Seminar

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



NTSB

NTSB

Maintenance-Related Safety Alerts

NTSB
SAFETY ALERT
National Transportation Safety Board

★ Proper Use of Fiber or Nylon Self-Locking Nuts ★

Inspecting nuts for age and condition and properly installing nuts is critical to ensuring tight connections

The problem

- Some pilots and maintenance personnel are not adequately inspecting or installing fiber or nylon self-locking nuts, which have fiber or nylon inserts incorporated into their construction to provide tight connections that will not loosen under vibration.
- Fiber or nylon self-locking nuts' ability to provide tight connections degrades with each use. They may not meet the minimum prevailing torque value, which can lead to loose connections or, eventually, liberate hardware and lead to accidents and incidents.

A new nylon insert. An old, degraded nylon insert.

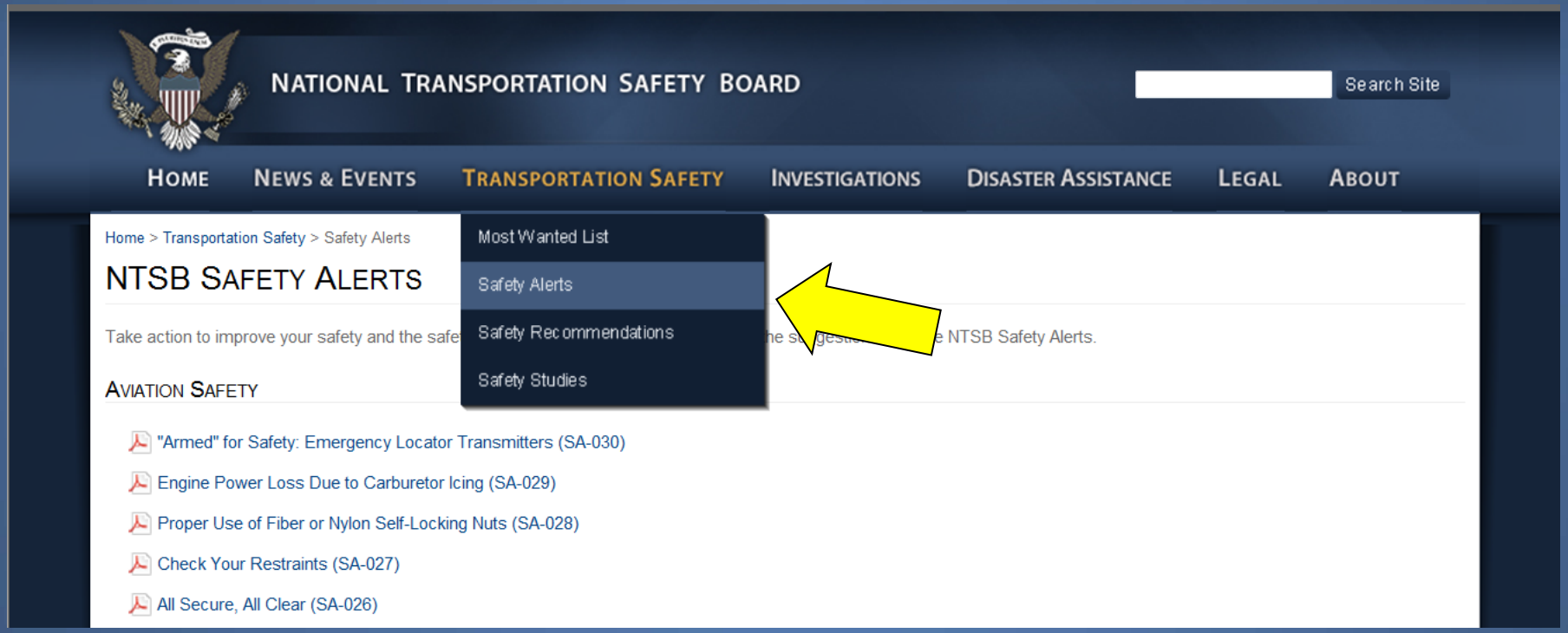
Related accidents

Sadly, the circumstances of each new accident are often remarkably similar to those of previous accidents. This suggests that some pilots and mechanics are not taking advantage of the lessons learned from such tragedies that could help them avoid making the same mistakes. The following accident summaries illustrate some common—and preventable—maintenance-related accident scenarios:

- A P-51 Mustang airplane collided with the airport ramp in the spectator box seating area following a loss of control during the National Championship Air Races. The investigation found that the trim tab attachment screws could be rotated through the nuts by hand, and the fiber inserts were visibly worn and displayed the full thread form. The degraded nuts allowed the screws to repeatedly loosen at race speeds, and, during the accident flight, led to aerodynamic flutter of the elevator trim tab and the subsequent loss of airplane control. The commercial pilot and 10 people died and about 64 people were injured. (NTSB accident number WPR11MA454 and report number AAB-12-01.)

- Proper use of self locking nuts
- Risk management for maintenance techs
- Ensuring ELTs are properly mounted and installed

WWW.NTSB.GOV



NTSB

Safety Alert Video

NATIONAL TRANSPORTATION SAFETY BOARD

Search Site

HOME | NEWS & EVENTS | TRANSPORTATION SAFETY | INVESTIGATIONS | DISASTER ASSISTANCE | LEGAL | ABOUT

NTSB News

NTSB Announces its 2014 Most Wanted List.

Press Release | More Information

1 2 3

Accident Dockets | Safety Recommendations | Aviation Accident Database | Data & Stats | Training Center

NTSB
An Independent United States Federal Government Agency

The NTSB is an independent Federal agency charged by Congress with investigating every civil aviation accident in the U.S. and significant accidents in other modes of transportation-railroad, highway, marine and pipeline. more >

News @ NTSB

Tweets Follow

Most Wanted List: Preserving a Safe Path Home wp.me/p1lQdj-A2

Show Summary

NTSB @NTSB 11h

Preliminary report on the Jan. 5 crash of a Canadair CL-600 in

NTSB

National Transportation Safety Board

Loss of Control
Eurocopter AS350

Las Vegas, Nevada
December 7, 2011

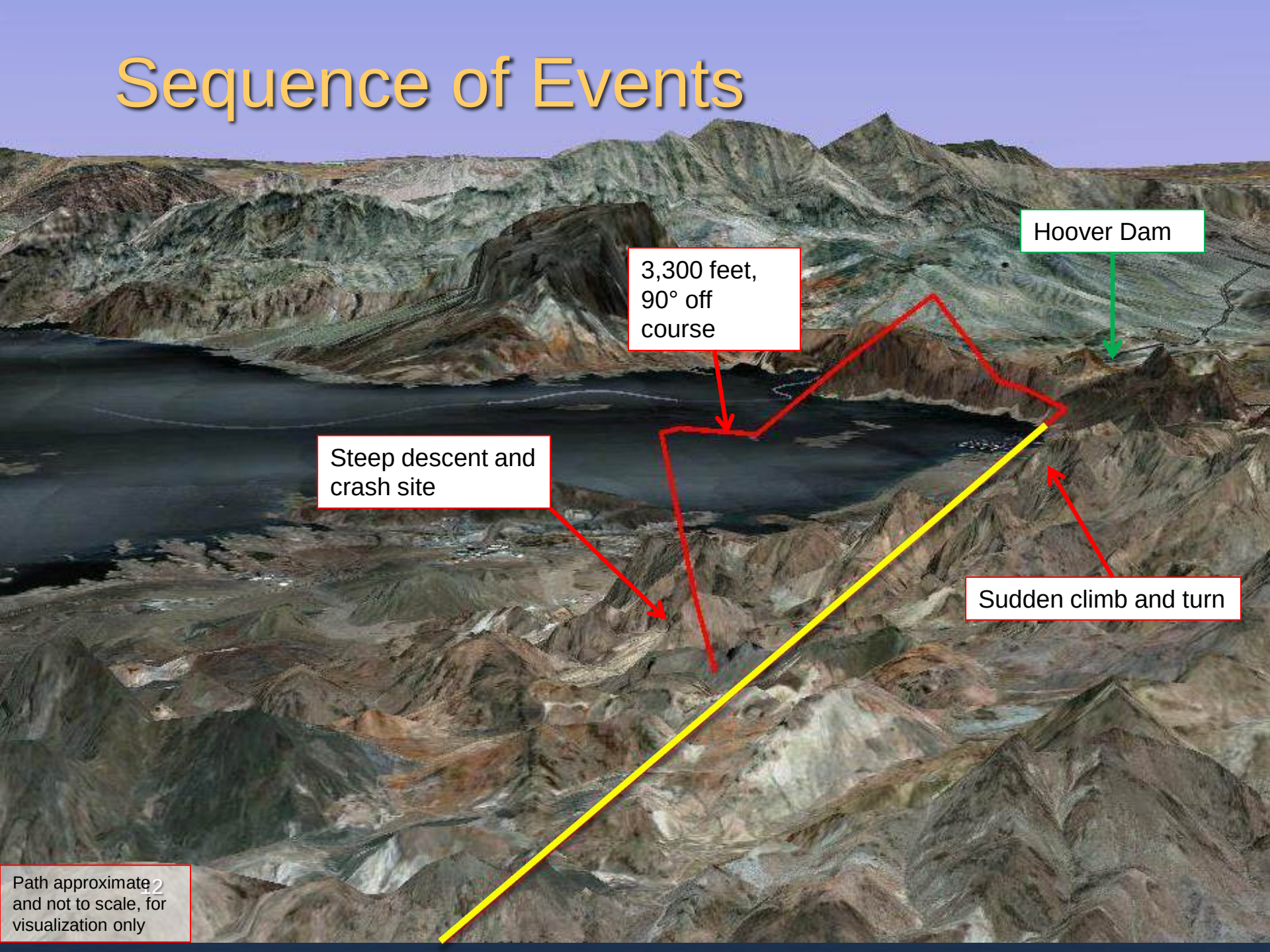
Initial Information

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

Flightpath

Path approximate and not to scale, for visualization only

Sequence of Events

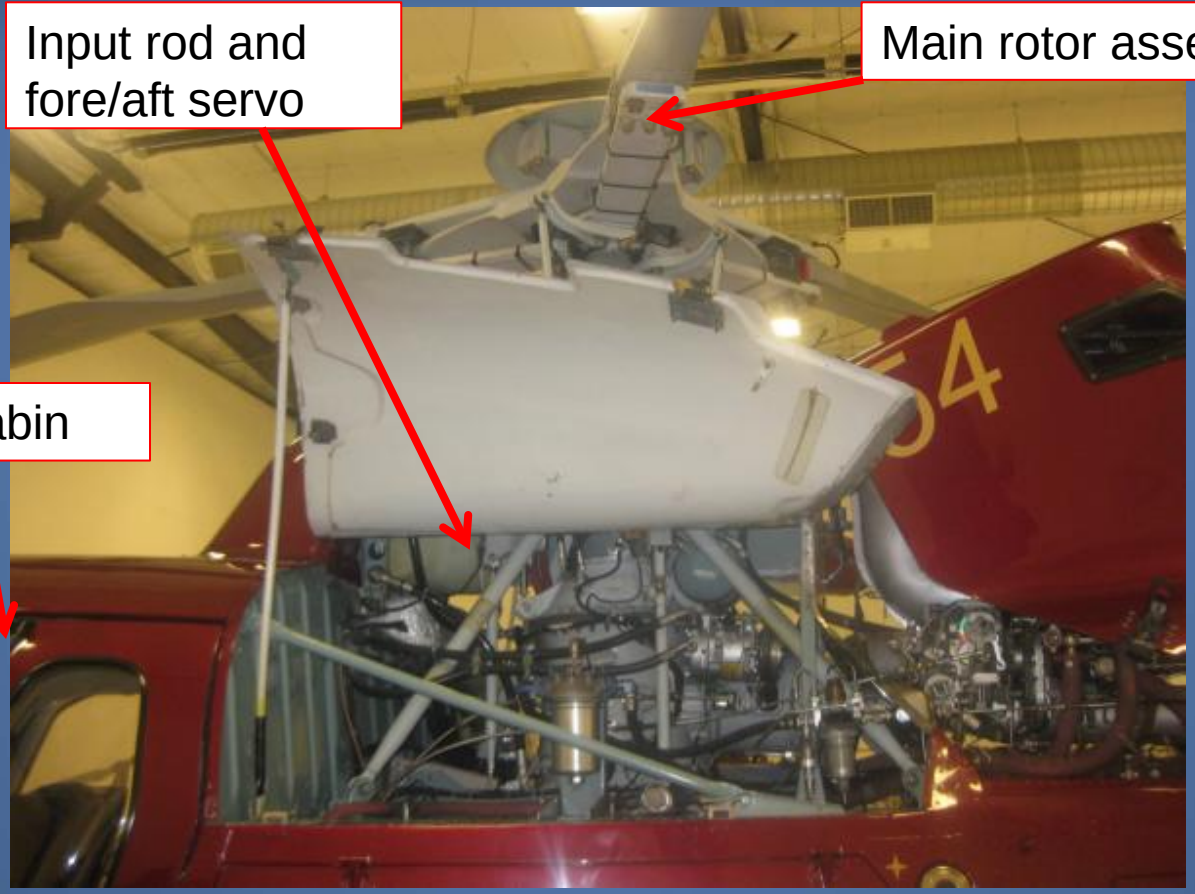


Fuselage
and engine

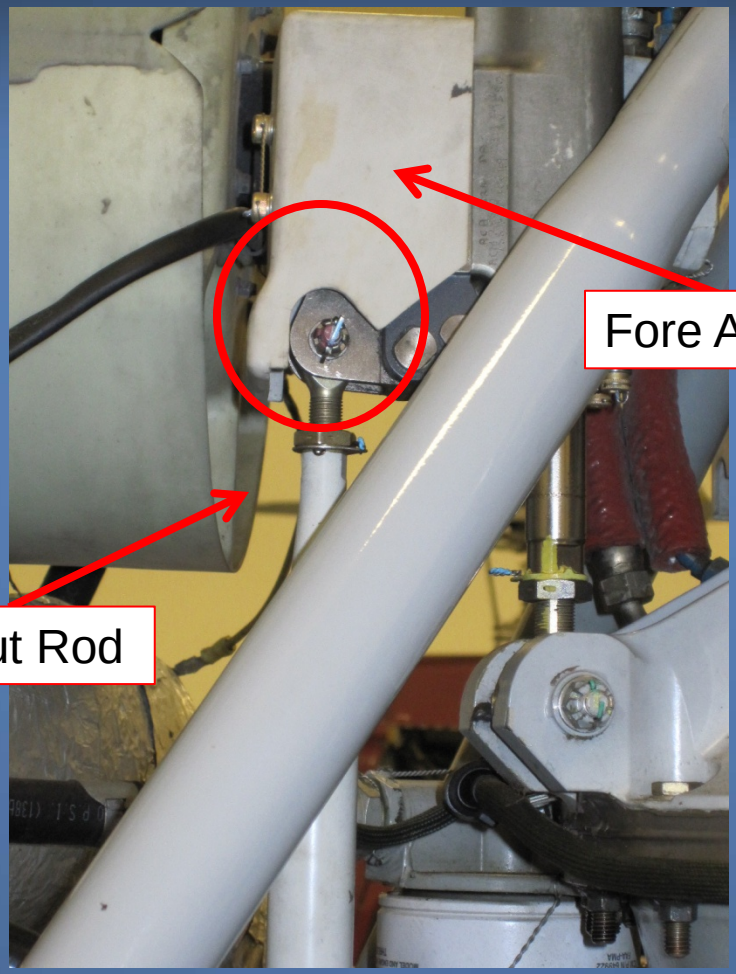
Events prior to accident

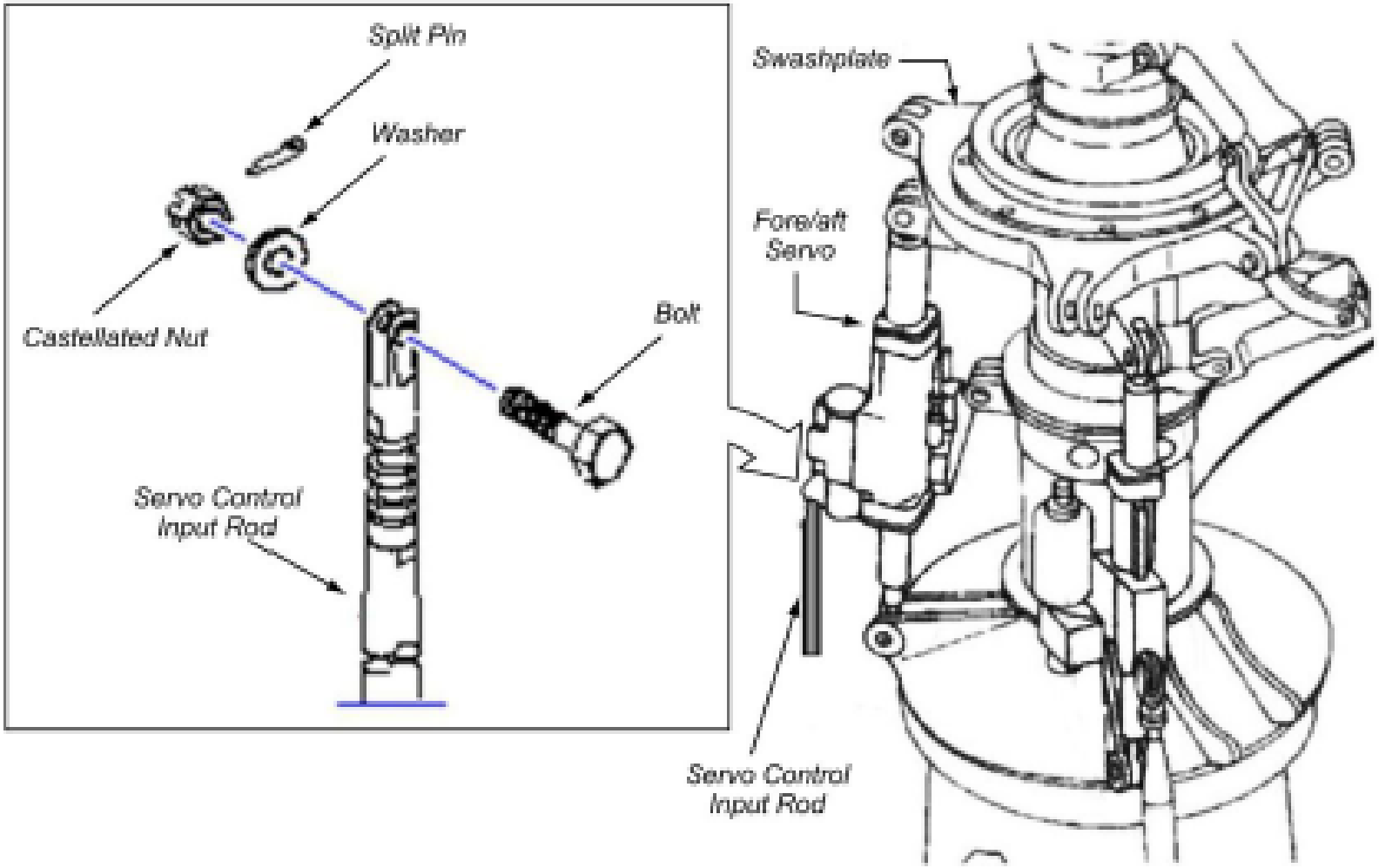
- 100-hour maintenance inspection conducted the day prior
- Fore/aft servo replaced
- Check flight flown
- 2 tour flights flown
- Accident occurred on
  - Third tour flight
  - 3.5 flight hours after maintenance

View of Helicopter Components



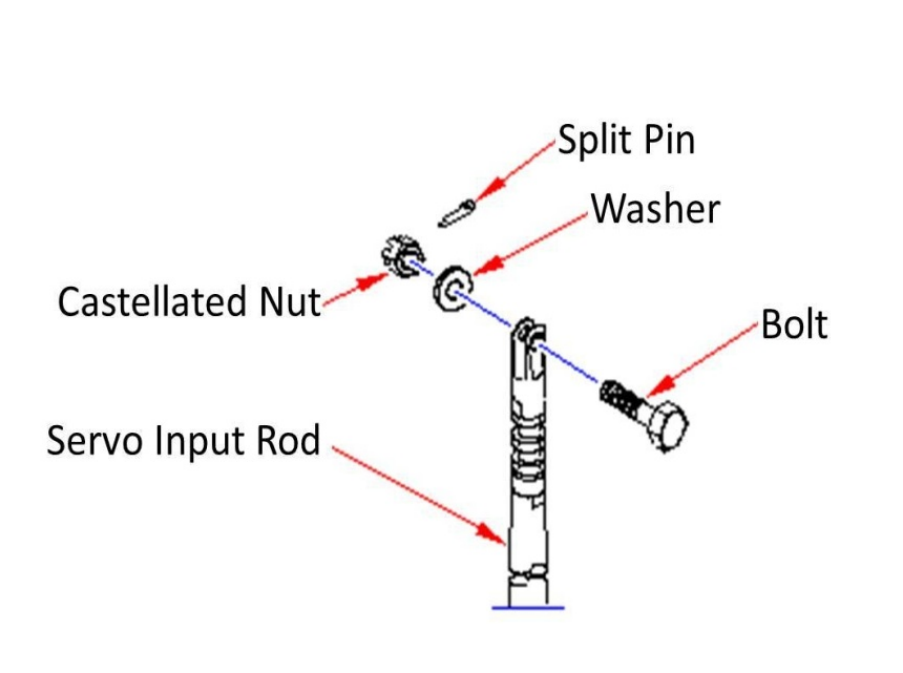
Installed Connection



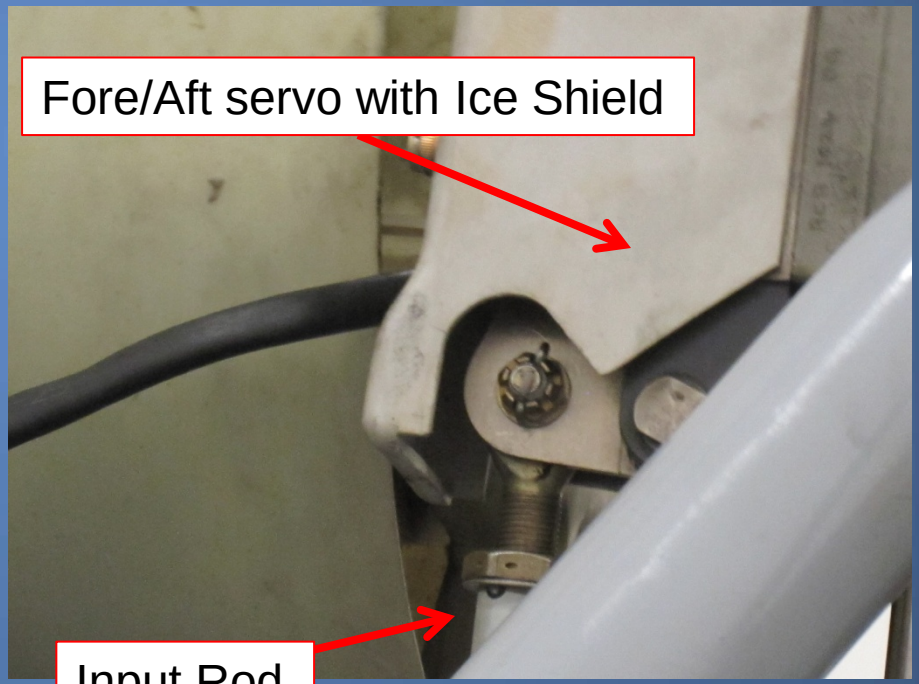

Split Pin
Washer
Castellated Nut
Bolt
Servo Control Input Rod
Swashplate
Fore/aft Servo
Servo Control Input Rod

Hardware

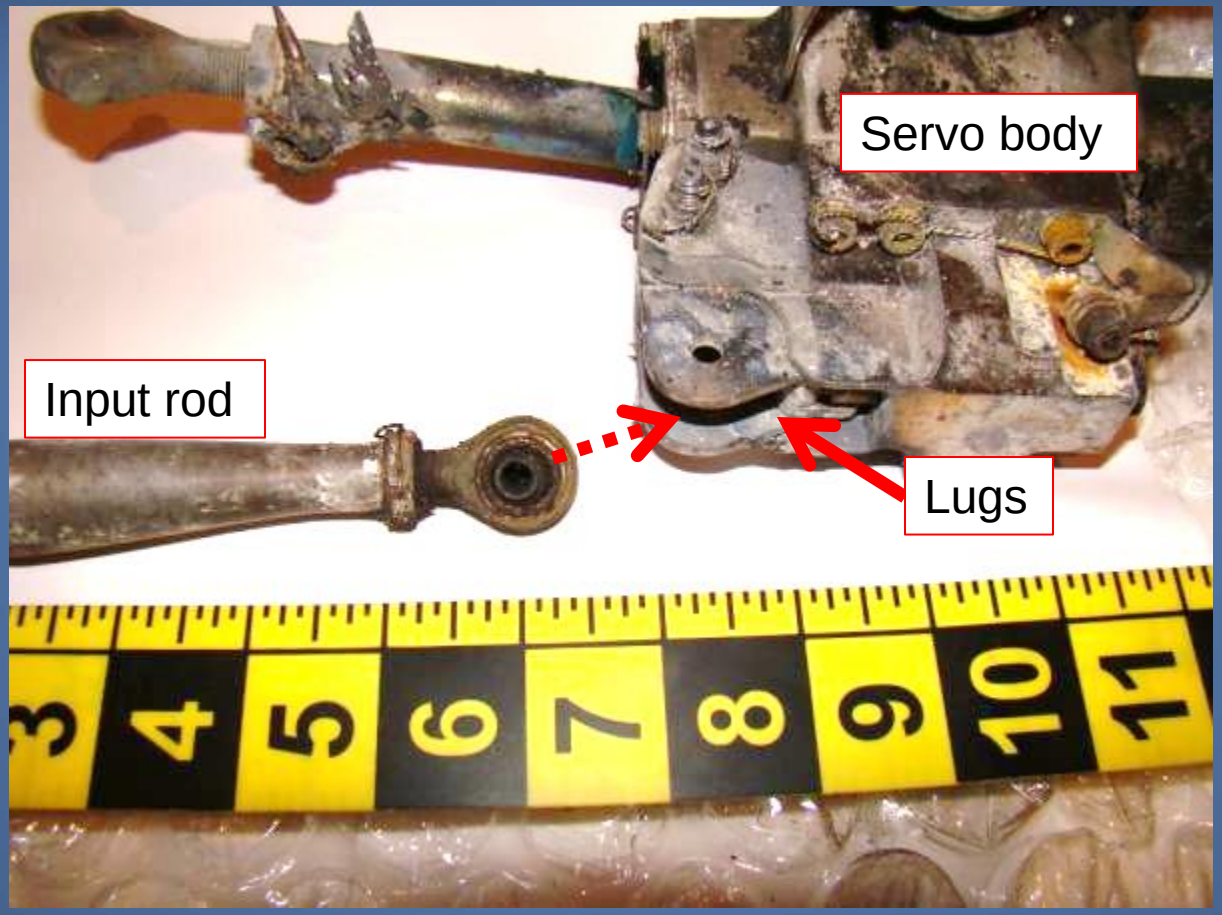
Input rod hardware



Hardware installed



Input Rod and Servo



Safety Issues Identified

- Reuse of degraded self-locking nuts
- Maintenance personnel fatigue
- Lack of human factors training for maintenance personnel
- Lack of work cards with delineated steps

National Transportation Safety Board

Maintenance Issues

Maintenance Performed day prior to accident

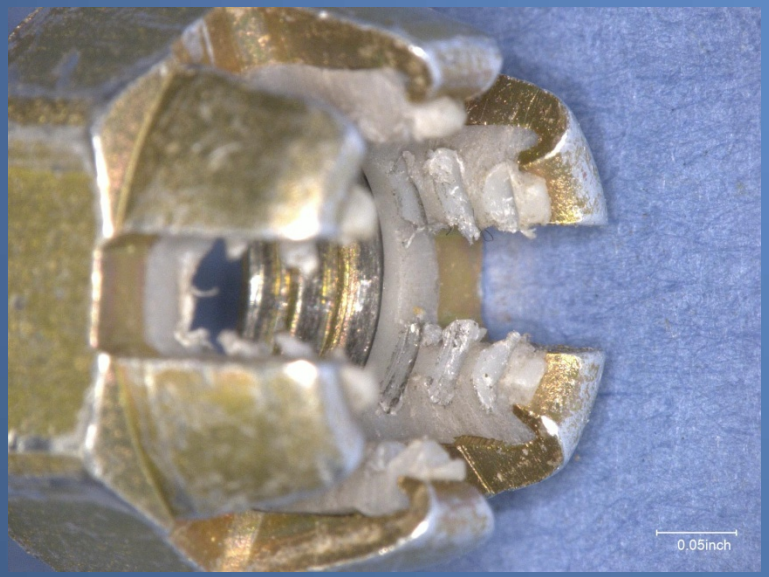
- 100-hour inspection
- Replacement of the following:
  - Engine
  - Fore/aft and tail rotor servos

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.

Post-maintenance Inspection and Check Flight

- Mechanic and inspector completed inspection
- Helicopter check flight conducted
  - Hydraulic belt tension
  - No flight discrepancies

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."

FAA Actions

- GA Maintenance Alert Issued - November 2012
- Aviation Maintenance Alert to be issued - Early 2013
- Updated inspection authorization renewal training begins - Spring 2013

National Transportation Safety Board

Human Performance Issues

Maintenance and Inspection Errors

- Improper securing of the fore/aft servo
- Improper tension of the hydraulic belt
- Incomplete maintenance inspection

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

Maintenance Personnel Fatigue

- Effects of fatigue
  - Difficulty sustaining attention
  - Memory errors
  - Lapses in performance

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%)

NTSB Finding

- “Because both the mechanic and the inspector had insufficient time to adjust to working an earlier shift than normal, they were experiencing fatigue during the December 6 shift.”
- “In addition, the mechanic had an inadequate amount of sleep and the inspector had a long duty day, both of which also contributed to the development of their fatigue.”

NTSB Finding

"Both the mechanic's performance and the inspector's performance probably were degraded by fatigue, which contributed to the improper securing of the fore/aft servo connection hardware, the improper installation of the hydraulic belt, and the incomplete maintenance inspection of the accident helicopter, respectively."

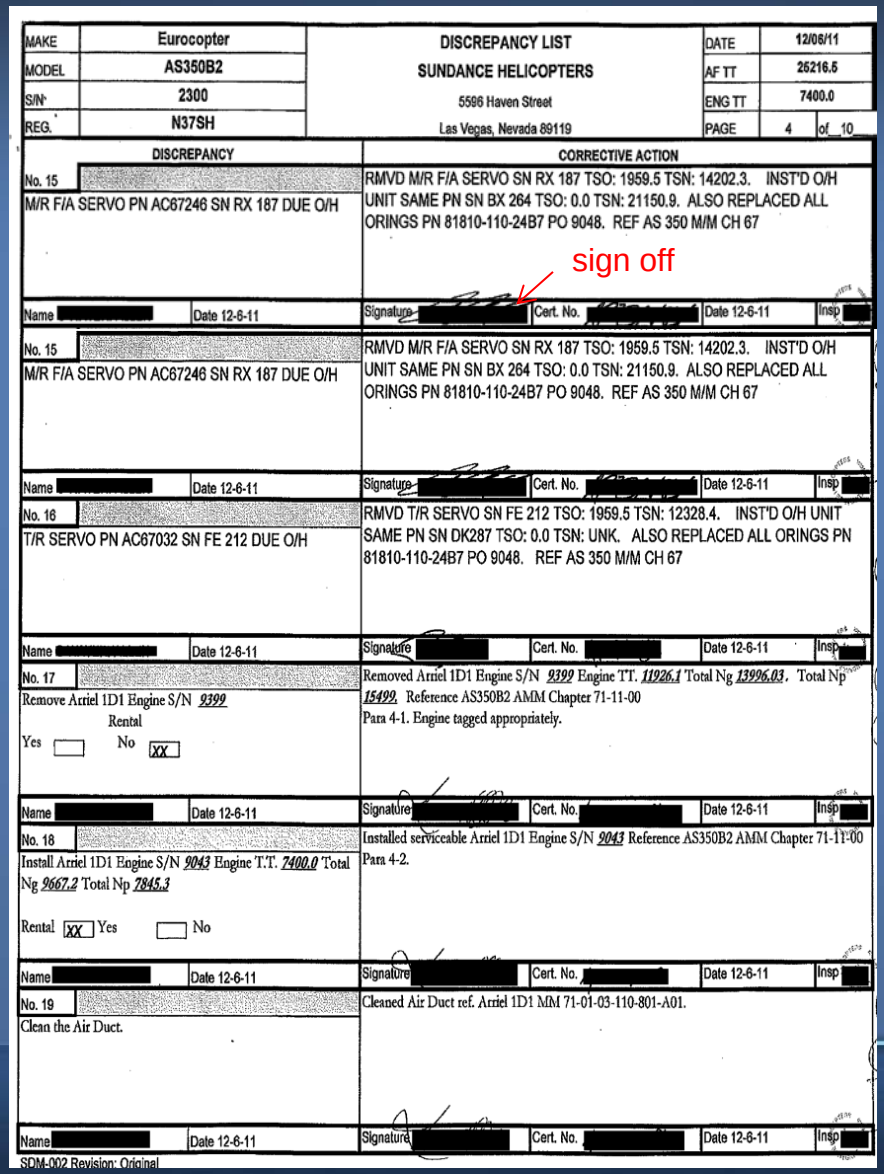
Human Factors Training

- Causes of fatigue, its effects, and countermeasures
- Fatigue education as part of a training curriculum
- No human factors training requirement in United States

Work Cards With Delineated Steps

- Paperwork for 100-hour inspection
- Inspector signoff for overall fore/aft servo installation
- No specific signoffs for critical steps within task

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

NTSB

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

NTSB

National Transportation Safety Board

Probable Cause and Recommendations

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 working under 14 *Code of Federal Regulations* Parts 121, 135, 145, and 91 Subpart K that take into consideration factors such as start time, workload, shift changes, circadian rhythms, adequate rest time, and other factors shown by recent research, scientific evidence, and current industry experience to affect maintenance crew alertness."

Recommendation

"Encourage operators and manufacturers to develop and implement best practices for conducting maintenance under 14 *Code of Federal Regulations* Parts 135 and 91 Subpart K, 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."

Recommendation

"Require that personnel performing maintenance or inspections under 14 *Code of Federal Regulations* Parts 121, 135, 145, and 91 Subpart K receive initial and recurrent training on human factors affecting maintenance that includes a review of the causes of human error, including fatigue, its effects on performance, and actions individuals can take to prevent the development of fatigue."

National Transportation Safety Board