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AIRCRAFT ACCIDENT INVESTIGATION REPORT

**AERO ASAHI CORPORATION
MCDONNELL DOUGLAS MD900 (ROTORCRAFT)
JA6757
ATSUGI AIRFIELD, AYASE-CITY
KANAGAWA PREFECTURE
AROUND 11:21 JST, SEPTEMBER 14, 2004**

January 26, 2007

**Aircraft and Railway Accidents Investigation Commission
Ministry of Land, Infrastructure and Transport**

The investigation for this report was conducted by Aircraft and Railway Accidents Investigation Commission, ARAIC, about the aircraft accident of Aero Asahi Corporation's McDonnell Douglas MD900 in accordance with Aircraft and Railway Accidents Investigation Commission Establishment Law and Annex 13 to the Convention of International Civil Aviation for the purpose of determining cause of the aircraft accident and contributing to the prevention of accidents and not for the purpose of blaming responsibility of the accident.

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Junzo Sato
Chairman,
Aircraft and Railway Accidents Investigation Commission

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**ATSUGI AIRFIELD, AYASE-CITY, KANAGAWA PREFECTURE
AROUND 11:21 JST, SEPTEMBER 14, 2004**

December 13, 2006

**Adopted by the Aircraft and Railway Accidents Investigation Commission
(Air Sub-committee Meeting)**

Chairman Junzo Sato

Member Yukio Kusuki

Member Susumu Kato

Member Noboru Toyooka

Member Yukiko Kakimoto

Member Akiko Matsuo

1 PROCESS AND PROGRESS OF THE ACCIDENT INVESTIGATION

1.1 Summary of the accident

On Tuesday September 14, 2004, a McDonnell Douglas MD900 operated by Aero Asahi Corporation, registration JA6757, was on a return flight to Tokyo Heliport. Around 10:07 Japan Standard Time (JST) ¹the aircraft lost yaw control, followed by No.2 engine failure. The aircraft tried to make an emergency landing at Atsugi airfield around 11:21, however, ended up a hard landing at west apron of the airfield.

Crewmembers on board were slightly injured.

The aircraft sustained substantial damage. No post-crash fire broke out.

1.2 Outline of the Accident Investigation

1.2.1 The investigative organization

On September 14, the Aircraft and Railway Accidents Investigation Commission (ARAIC) received an Accident Notice and assigned an investigator-in-charge and one investigator.

1.2.2 Accredited representative and adviser by foreign authorities

Accredited representative from the United States, the state of design and manufacture of the aircraft, participated in the investigation.

1.2.3 The implementation of the investigation

The investigation proceeded as follows.

September 14	Investigation at the accident site
September 15	Collection of crew statements
September 17 - 18	Examination of the accident aircraft
September 22 – February 10, 2006	NOTAR fan close examination
February 2, 2005	Accident aircraft examination by commission members

1.2.4 Notification of factual information to Civil Aviation Bureau

On October 4, ARAIC provided Civil Aviation Bureau (CAB) with factual information stating that a tension-torsion (T-T) strap, which is a part of NOTAR® fan assembly was fractured.

1.2.5 Investigation status report

On November 25, 2005, ARAIC submitted a status report of investigation to the Minister, of Land, Infrastructure, and Transport

1.2.6 Comments from persons relevant to the cause of the accident

The comments were submitted from the pilot and the Aero Asahi Corporation.

1.2.7 Comments from the participating state

¹ Unless otherwise indicated, all times are JST, based on a 24-hour clock.

The comments on the draft report were invited from the United States.

2 FACTUAL INFORMATION

2.1 History of flight

Aero Asahi Corporation's MD900, registration JA6757, was on a return flight to Tokyo heliport originating from Fujiurakona helipad with a refueling stop at Shizuoka heliport. Around 10:07 the aircraft lost yaw control followed by No.2 engine failure, the pilot decided to make an emergency landing at Atsugi airfield (RJTA) in Ayase city, Kanagawa prefecture. The aircraft ended up a hard landing at west apron in the airfield.

Maintenance log states that no anomalies were found in the preflight check done by the pilot and the mechanic at Fujiurakona helipad.

The outline of the flight plan filed to Tokyo Airport Office was as follows.

FLIGHT RULES: VFR

DEPARTURE AERODROME: Shizuoka heliport

ESTIMATED OFF BLOCK TIME: 09:40

CRUISING SPEED: 120kt

CRUISING ALTITUDE: VFR

ROUTE OF FLIGHT: Odawara – Fujisawa

DESTINATION AERODROME: Tokyo heliport

ENDURANCE: 2 hours 00 minutes

PERSONS ON BOARD: 2

The progress of the flight up to the accident after take-off from Shizuoka heliport was stated by the pilot and the mechanic as follows.

(1) Statement by the pilot

We took off from Shizuoka heliport at 09:35. Around 10:07 while flying over Fujisawa at 120kt, 1,500ft, I heard a repetitive banging noise and felt vibrations originating from the aft fuselage. Given the facts that Integrated Instrument Display System (IIDS) generated "CHECK NOTAR² BALANCE" message some time after take-off, small but steady increment of the vibration level was confirmed by the mechanic on board, and higher vibration level than the day before, I figured that something wrong occurred to NOTAR system. I had no response from rudder inputs. In about 30 seconds, "No.2 ENG CAU" illuminated with engine-out aural warning, and No.2 engine stopped. IIDS generated "EEC (Electronic Engine Control)" and "FAIL". In case you get those two messages engine restart is impossible. I decided to turn back to Sagami bay and kept flying in that direction for a while. But No.1 engine was running normally, so I changed heading again for Tokyo. Later I judged it's not appropriate to fly over built-up area, and with advice from my company I decided to hold over Shinomiya helipad which is located near Sagami river mouth. Switches governing No.2 engine were turned off by the mechanic before reaching shore line. I had about 650lb of remaining fuel when I started holding there. I continued holding to burn remaining fuel to reduce aircraft weight paying special attention to the No.1 engine condition,

While I was holding there I received advice from my company to land at Atsugi airfield. I declined it once because I didn't like to fly over built-up area to reach there. During the about an hour holding I checked to what extent I could control the aircraft. At 100kt, straight flight was possible with

² NOTAR is a registered product name of the manufacturer.

some left bank angle, however, in order to maintain the air speed, I had to push cyclic forward. This caused altitude loss due to single engine operations. At 90kt, I could maintain altitude, however, the aircraft had a tendency to make a gentle right turn. For a straight and level flight, I had to bank the aircraft 10° left with yawing about 10° to the right. Stable right descending turn was possible above 80kt. Right spin started below 80kt. Recovery from spinning was possible by descending with nose down attitude. Due to the single engine situation I could not climb higher than 1,200ft.

Power lines are strung near the river mouth and Shinomiya helipad was too small to land for the aircraft lacking in yaw control. I finally made up my mind to land at Atsugi airfield.

I left Shinomiya around 11:10 and headed for Atsugi airfield. There was an inbound traffic to the airfield and I stayed over the point about 5nm SW because I didn't want to trouble Atsugi airfield personnel. After another right circling 1nm S around 11:20, I made an approach into the airfield. I contacted the control tower and told I would land after confirming my intended landing area.

Wind was from 080° at 3kt and this was not suitable for running landing for runway 01, so I decided to land from the north.

I figured that landing on the grass area would be easier and safer for running landing rather than landing on the runway, with a possibility of roll-overs in case of veering off. I approached the airfield from SW and made a right circling to land the aircraft on the grass area near the center helipad. I applied small right cyclic input to align the aircraft to the runway direction and the aircraft started right spinning. I was cautious not to reduce airspeed less than 80kt, however, airspeed may have been reduced unintentionally. The height above ground at that time was 200ft and I tried to stop the spinning, however, I couldn't make it maybe due to lack of airspeed. Spinning continued and it ended up a hard landing. I couldn't manage the aircraft to land, but I felt that the aircraft fell by itself. Spinning was rapid that I could feel lateral gs. All I tried was to maintain level attitude.

After the spin stopped on the ground I evacuated the aircraft. (2)Statement by the mechanic

After the take-off and just before reaching Atami, IIDS generated "CHECK NOTAR BALANCE" message. Then vibration level measured somewhere between 0.3 and 0.35ips. I measured it using IIDS three or four times after that before passing Fujisawa and the level increased little by little and eventually reached 0.6ips.

Flying between Fujisawa and Ofuna, I heard a bang and felt vibrations. The pilot checked rudder pedals and found loss of yaw control. Right after that "EEC" and "FAIL" messages for No.2 engine were generated on IIDS, and No.2 engine smoothly stopped without seizing. I heard the aural warning for engine stop. After the engine stop we flew toward Tokyo for a while and changed the course to Shonan shoreline near Higashitotsuka. We held over Sagami river mouth more than one hour. Before reaching Atsugi airfield I collected such unsecured objects as documents and a tool box in the cockpit and relocated them in the aft cabin and secured them. We retightened our safety belts. The pilot's aiming point for landing seemed to be the helipad in the grass area which lies beside the runway. When he decelerated the aircraft, it began to spin. I noticed the onset of spin, but I didn't know the trajectory of the aircraft after that. I braced myself holding the window frame. The pilot was trying to keep the cyclic stick upright, although his body was leaning forward.

After the spinning stopped on the ground, I turned off engine related switches. I don't remember the engine was still running or not at that time. After getting out of the aircraft, the main rotor was still turning. So I applied the rotor brake. The pilot asked me to turn off the battery switch and I did

so. I disconnected battery connectors in the nose section, and removed two oxygen bottles for MEDEVAC use out of the cabin.

The accident site is located on the west apron of Atsugi airfield in Ayase city, Kanagawa prefecture, and it occurred around 11:21, September 14, 2004.

(See figures 1, 2 and Picture 1)

2.2 Injuries to persons

The pilot and the mechanic suffered minor injuries.

2.3 Damage to the aircraft

2.3.1 Degree of damage

The aircraft was substantially damaged.

2.3.2 Aircraft damage by part

(1) Fuselage and tail boom	Damaged
(2) Skids	Damaged
(3) Main rotor blades	Damaged

2.4 Damage to the properties

None

2.5 Personnel information

Pilot: Male, age 50

Commercial License (Rotorcraft)

Date of issue

December 16, 1977

Type Ratings

Land, Multi Turbine engine

Class 1 Airman Medical Certificate

End of validity

May 19, 2005

Total flight time

9,512 hours 34 minutes

Flight time, last 30 days

28 hours 27 minutes

Total flight time on MD900

540 hours 37 minutes

Flight time, last 30 days on MD900

6 hours 00 minutes

2.6 Aircraft Information

2.6.1 Aircraft

Type

McDonnell Douglas MD900

Serial number

900-00018

Date of manufacture

May 24, 1995

Certificate of airworthiness

No. Tou-16-257

End of validity

August 22, 2005

Airworthiness category

Rotary aircraft, Normal or Special Aircraft (X)

Total time in service	1,735 hours 31 minutes
Flight time since last scheduled 12-month maintenance check (July 20, 2004)	25 hours 33 minutes

(See Figure 3)

2.6.2 Engines

Type: Pratt and Whitney Canada PW-206A

	Serial No.	Date of manufacture	Total time in service
No.1	PCE-206016	December 15, 1993	1,735 hours 31 minutes
No.2	PCE-206033	September 26, 1994	1,735 hours 31 minutes

2.6.3 Weight and Center of Gravity

The weight of the aircraft at the time of the accident was estimated to be approximately 4,840lb, with the position of center of gravity at 200.2in, both being within the allowable limits (cf. Maximum certificated weight is 6,250lb. Allowable center of gravity range corresponding to the weight of 4,840 lb is between 196.0in and 206.0in.)

2.6.4 Fuel and lubricating oil

The fuel on board was JET A-1. Oil on board was Mobile Jet Oil II.

2.7 Meteorological Information

Weather observed at Atsugi Airfield near the time of the accident was as follows:

11:00 Wind direction 050°, Wind speed 04kt, Visibility more than 10km, Cloud amount 4/8, Cloud type Altocumulus, Ceiling 10,000ft, Temperature 31°C, Dew point 20°C, QNH 29.95inHg

2.8 Information on the accident site and the debris

2.8.1 Accident site

The accident site is on the west apron which is about 570m NNE from the control tower of Atsugi airfield. Impact marks grooved by landing skids and tail skid orienting to 050° were left on the spot where the aircraft landed. Tip part of broken tail skid was found about 3m S of the tail skid mark. Skidding marks made by skids and scratch marks by main rotor blades' tips were left on the apron. Skidding marks extended SE from the first landing point to the aircraft final resting point measured about 20m.

The aircraft rested orienting to 080°.

2.8.2 Detailed information of the aircraft damage

(1) Fuselage: Its lower and right aft portion were damaged and cracks were found in upper fwd portion and tail boom attaching point. No fuel leak was found

(2) Landing gear: Forward and aft cross tubes were bent outwards.

(3) Main rotor blades: Each main rotor blade was damaged in the portion about 1m from its outer end

(4) Crew seats: An energy attenuating seat frame has about 17cm stroking distance. Both seat pans were found about 3cm lower than the original position.

(5) NOTAR fan: Among 13 fan blade assemblies, one assembly was fractured and was found in the jet thruster section located at aft end of the tail boom. The T-T strap of the

assembly was fractured. Remaining fan blades were all damaged. (6) NOTAR fan drive shaft: It was fractured into three portions. The flexible coupling at the transmission side was broken and anti-flail device built in the coupling to be mentioned in 2.12.3, was detached. Driveshaft-side part of the broken flexible coupling had no scratch marks on it. (7) Fuel line: Fuel line to No.2 engine was fractured at frangible valve on the engine deck. No fuel leak from the fuel tanks was found. (See Figure 5, Pictures 2, 3 and 4)

2.9 Rescue operations

Headquarters, 4th Air Wing, Japan Maritime Self Defense Force (JMSDF) was notified of an emergency landing request from Aero Asahi Corporation around 11:05. Around 11:06 Atsugi Ground Rescue Team was put on stand-by by the runway around 11:17 with 18 personnel, a command vehicle, a chemical fire engine and an ambulance. Atsugi Rescue Squadron put a UH-60J rescue helicopter on stand-by with engine running to cope with the situation. Around 11:25 Ground Rescue Team picked up the pilot and the mechanic of the accident aircraft and sent them to JMSDF medical facility.

2.10 Recorded image of the emergency landing

All sequence of the emergency landing was videotaped by a JMSDF personnel. Recording contained all the aircraft movement from the onset of right spin to its final resting including motions such as eight turns of spins in the air, hard landing in level attitude, fuselage tilting to right with main rotor blades smashing the ground concurrently skidding south-eastward. (See figure 2)

2.11 Tests and research to find facts

To find the reason why the T-T strap was fractured, thirteen (13) T-T straps including the fractured one, were sent to the aircraft manufacturer and were put under detailed examination under the witness of NTSB investigators. The result³ of the examination was as follows. (1) Construction of T-T strap

A T-T strap is a composite material which is made of Kevlar49 fibers continuously wound around two (2) corrosion-resistant metal spools and impregnated in polyurethane. The outer surface is coated with polyurethane.

(See Picture A, attached document "Examination result")

(2) Mechanical tests

Each of the twelve (12) intact straps was subjected to the tests for tension load and torsion load respectively at the strap manufacture's facility. Compared to the records of tests at the time of manufacture of T-T straps, all tested straps have strength and stiffness of the specifications. (3) X-ray Radiographs

Thirteen (13) T-T straps were X-ray photographed viewing paralleled to the spool axis. The photographs show that all T-T straps have dark line shadows parallel to fibers (longitudinal) in the area where the fibers closest to the spool hub intersect the edge of flange of either or both spools.

(See Picture B, Examination result)

The X-ray radiograph examination⁴ of a T-T strap recovered from a similar accident in Mesa

³ NTSB Material Laboratory Factual Report, Report No. 05-103

⁴ NTSB Material Laboratory Factual Report, No. 05-102

(AZ) (See 2.12.9) showed transverse shadow which is perpendicular to fibers, as well as longitudinal shadows, in the aforementioned area.

(4) Fractographic examination

a. Examination of two fracture surfaces of the fractured T-T strap showed that there are three flat areas where a groups of fibers were cut at the same location, . Each flat fracture area is labeled “Area 1”, “Area 2”, and “Area 3” as shown in picture C. Area 1 and Area 2 are point symmetric about the longitudinal centerline of the strap. In the area being point symmetric to Area 3 shows no similar flat fracture area, however, some fibers were fractured there.

(See Picture C, Examination result)

b. Blade-assembly-side of fractured T-T strap was sectioned in two planes, one which is perpendicular to spool axis, and the other which is nearly parallel to the spool axis. Sliced sections were mounted in epoxy and polished for scanning electron microscopy (SEM) observations.

In the piece sectioned perpendicular to the spool axis, fiber kinking⁵ was observed at the location corresponding to the location where the fibers closest to the spool hub intersected the edge of the spool flange. The fiber kinking was observed extending across most of the fiber-reinforced area. Several longitudinal cracks were also observed in the same region.

In the piece sectioned parallel to the spool axis, transverse fiber kinking was observed at the location corresponding to the location where the fibers are closest to the spool hub intersected the edge of the spool flange. (5)Finite element modeling of T-T strap

Finite element modeling⁶ of T-T strap was undertaken in order to investigate the deformation of the composite material in the area closest to the edge of the spool, when the centrifugal force by the NOTAR fan rotation and the torsion displacement by the pilot pedal input were applied.

The result revealed that when the torsion displacement was applied without tension stress, a strain concentration was observed where the composite material is closest to the edge of the spool, changing from a large compressive (positive) strain to a large shear (negative) strain over a short distance, and this compressive strain is smaller when tension and torsion stress coexisted.

2.12 Other necessary information

2.12.1 NOTAR fan maintenance record per the maintenance manual

(1) Maintenance cycle and checked items

a. 100 hour check

Fan blade condition

b. 12 month check

- Fan blade condition
- Hub assembly condition
- Pitch change mechanism condition

c. 600 hour check (when a NOTAR fan system is dismantled form the helicopter)

- Fan support bearing condition, oil servicing
- Fan pitch bearing condition, oil servicing.

(2) Maintenance record

⁵ A phenomenon specific to fiber reinforced material which is compressed longitudinally

⁶ NTSB Material Laboratory Factual Report, Report No. 05-125

- a. NOTAR fan assembly was checked clear on August 15, 2002, as part of 600 periodical check.
- b. NOTAR fan assembly was checked clear on July 20, 2004, as part of 12 month check.
- c. During the period between above mentioned a. and b., no non-scheduled maintenance which requires dismounting of NOTAR fan were done to the system.

2.12.2 Fractured T-T strap

The fractured T-T strap's part number is 900R3442009-101 and serial number is LK0024. Its total time in service was 1,735 hours 31 minutes, with remaining service time of 764 hours 29 minutes.

2.12.3 NOTAR fan drive shaft

The drive shaft has a flexible coupling on either end and the shaft connects the transmission and the NOTAR fan assembly. Anti-flail device, a bearing-like device, being built into the flexible coupling, enables the shaft to maintain integrity and prevents the shaft from inflicting damage to neighboring parts, by releasing twisting force and making itself spin freely upon quick destruction of flexible coupling.

2.12.4 No.2 engine

No.2 engine's compressor turbine and power turbine rotated without restriction when turning force was applied by hand.

2.12.5 NOTAR

(1) NOTAR system function

NOTAR was invented to substitute conventional tail rotor. NOTAR fan housed in the aft fuselage pushes large amount of low pressured air into the tail boom. The air is released through slits cut in the right side of the tail boom and jet thruster. The air released through the slits flows along the tail boom surface by Coanda effect. Under the effect of main rotor downwash, tail boom acts like a wing and produces lift toward right when observed from aft and this becomes a part of anti-torque. During hovering anti-torque is compensated for with thrust generated by jet thruster. While in forward flight ratio of anti-torque produced by vertical fins increase as the airspeed increases, whereas anti-torque produced by Coanda effect decreases.

(See Figure 4)

(2) System components

NOTAR fan is driven by transmission through NOTAR fan driveshaft. NOTAR fan consists of 13 variable-pitch blade assemblies, fan hub center, spline assembly and other parts. A blade assembly is secured to spline assembly with a T-T strap. Each T-T strap enables its fan blade's pitch change.

(See Figure 5)

2.12.6 NOTAR fan vibration

(1) On the day before the accident

IIDS generated "CHECK NOTAR BALANCE" message around 15:50 and 16:20 on September 13, 2004. Measured vibration level was 0.3ips respectively. The mechanic made a visual inspection of the NOTAR fan at Fujiurakona helipad, however, he found no anomalies.

(2) The maintenance manual requires vibration check at 12 month inspection. If the level exceeds

0.05ips, it shall be reduced to less than 0.05ips by adjusting balance weights. When rotating parts of NOTAR fan assembly were replaced at unscheduled maintenance work, vibration check is required and vibration level shall be reduced below 0.05ips.

(3) IIDS message

Vibration messages generated by IIDS are advisory, and these do not restrain flights. Without IIDS message advisory no vibration check is needed.

(4) According to the information obtained directly from the manufacturer, the logic of the “CHECK NOTAR BALANCE” message and measures to be taken are as follows. However, it does not specify allowable maximum level.

The threshold vibration levels are 0.3ips and 0.6ips. If vibration level exceeds 0.3ips when measured at 2 minute interval while the IIDS is not operated, it is counted as 1 sample, and when 5 samples are accumulated “CHECK NOTAR BALANCE” message is generated. However, if vibration level decreases less than 0.3ips within 5 samples, counted samples reduce to zero. When “CHECK NOTAR BALANCE” message is cleared with the “CLR” key, new message will be generated only after accumulating five values which register larger than 0.6ips. When the IIDS is switched off, counting starts after registering 0.3ips.

2.12.7 Vertical fins

Vertical fins fitted on either end of the horizontal fin are actuated by yaw rate gyro signal and collective lever input, not by rudder pedal input.

2.12.8 Emergency procedures

The rotorcraft flight manual states “Anti-torque malfunction (all thrust loss) as follows;
3-9-2 ANTI-TORQUE FAILURE – COMPLETE LOSS OF THRUST

This involves a break in the fan drive system (i.e., a broken drive shaft) that causes the fan to stop turning resulting in a complete loss of fan thrust. Directional control becomes dependent on airspeed and power setting.

Indications: Inability to “trim” helicopter with pedals.

Condition: In Forward Flight

Procedures

- *Adjust airspeed and power for level flight between 80 and 100 KIAS.*

CAUTION: Do not attempt an autorotation from forward flight unless actual dual engine failure occurs.

- *Perform a shallow approach and running landing to a hard surface or other suitable area. If possible select an approach direction that offers a left quartering headwind to reduce the touchdown ground speed and the amount of right yaw.*

NOTE: Touchdowns made into the wind between 20 and 30 KIAS, may provide good directional control at reduced power (collective) settings.

- *An aggressive reduction in power (collective) as the aircraft is decelerated during the final approach should yaw the aircraft to the left.*
- *As the ground is neared, adjust collective as necessary to align the aircraft with the touchdown direction and cushion the landing.*

- *During ground run out, adjust collective to maintain directional control. If necessary, during touchdown and ground run out, reduce rotor RPM by rotating both twist grips simultaneously towards IDLE to assist in maintaining directional control.*

NOTE: Use of the twist grips to change RPM is generally not recommended due to the complexity of manipulating both twist grips simultaneously and now having both engines in the manual mode. If needed, it is recommended that they be used only to reduce RPM just prior to or at the moment of touchdown.

2.12.9 Similar accident

On September 8, 2004, the first NOTAR related accident occurred involving a MD900 (aircraft serial number 900-00016) in Mesa, Arizona, U.S.A. The summary of the accident is as follows.

The aircraft started take-off maneuver after 10 minute hovering. When it reached 30 – 40ft AGL it experienced severe vibration, the pilot aborted the take-off and lowered the collective to the lowest position and made a running landing to the runway. Landing speed was 30 – 40kt. Upon touchdown, the pilot had difficulty maintaining directional control. It ran about 100m and came to a rest 1m beyond the runway end.

Post-accident inspection revealed that one T-T strap was fractured at its root. The T-T strap's serial number was LK0959, its total time in service was 1,687 hours 00 minutes. No IIDS message was generated. NOTAR fan driveshaft was intact.

The NTSB determined the probable cause(s)⁷ of this accident as follows:

Fracture of T-T strap in the anti-torque fan due to progressive fiber failure of the composite strap material from compression and/or transverse shear stresses that occurred with repeated manipulation of the cockpit anti-torque control pedals without the fan operating at full rpm. A factor in the accident was the helicopter manufacturer's inadequate fatigue and load testing on the strap.

2.12.10 Crashworthiness

(1) The aircraft is designed based on “MD900 hard landing shock absorption design”. The fuselage, crew seats and landing gears exceed tighter airworthiness standard.

(2) Fuel tank has airworthiness and is constructed with materials that have anti-rupture capability against shock. Fuel lines have self-sealing capability.

⁷ NTSB Brief of Accident, File No. 19745 (adopted on May 30,2006)

3. Analysis

3.1 Aircrew certificates and medical certificates

The pilot had valid airman licence and airman medical certificate in accordance with applicable regulations.

3.2 Certificate of airworthiness

The aircraft had a valid certificate of airworthiness and was maintained in accordance with applicable regulations.

3.3 Relations with the weather conditions

The weather condition at the time of the accident was such that weak wind was blowing. It is considered that weather condition did not affect the aircraft spin before the hard landing on the apron.

3.4 Reason for the NOTAR fan driveshaft failure

Due to fracture of the T-T strap, one blade fan assembly was detached from the fan hub. Its blade was considered shattered into pieces and caused other blades to be shattered. The shattered pieces were considered trapped between rotating and non-rotating parts of fan assembly, causing a temporary seizure of the fan hub.

At this moment transmission-side flexible coupling was fractured and anti-flail device kept the driveshaft turning, however, it is estimated that the driveshaft, turning at very high rpm with rotating inertia was twisted and fractured at mid-length. Forward half of the driveshaft kept turning with its anti-flail device connected to the transmission, while its rear end wobbled and hit nearby parts. It is estimated that forward half of the driveshaft was fractured into two pieces during this sequence.

3.5 Reason for No.2 engine failure

As stated in 3.4, it is considered that forward half of the driveshaft wobbled around and fractured the No.2 engine fuel line at the frangible valve while it was connected to the transmission with anti-flail device.

As a result No.2 engine was considered to have failed due to fuel starvation. No fuel leak occurred because the fuel line's built-in self-sealing mechanism worked properly.

3.6 Reason for T-T strap fracture

Given the facts stated below, it is estimated that the T-T strap was fractured in the area where the composite material is closest to the edge of the spool as the result of the fatigue caused by the repetitive strains which gradually degraded the strap's integrity.

a. As stated in 2.11(4), in the area where the composite material is closest to the edge of the spool, there exists a group of fractured fibers at the same position making a flat area, kinked fibers, and cracks.

b. As stated in 2.11(3), radiograph analysis revealed shadows along longitudinal direction of strap and shadows perpendicular to this are estimated that they are the result of cracks and fractured or kinked fibers, respectively.

c. As stated in 2.11(5), computer analysis using finite element modeling revealed that a large

compressive and shear strain to a Kevlar fiber, which is known to have high tension strength but comparatively low compression strength, exist in the area where the composite material is closest to the edge of the spool.

According to the information provided by the NTSB, the manufacture's fatigue load test spectrum for T-T strap accounted for only the composite load which consists of the centrifugal force load by the NOTAR fan rotation and twist load by manipulation of rudder pedals, and did not account for the case of twist load which may only happen during preflight rudder check or under low NOTAR fan rotation. Those facts are estimated to have contributed to the generation of large compressive/shear strain in T-T straps.

3.7 Emergency procedures

It is estimated that the pilot, in accordance with the emergency procedures of the rotorcraft flight manual, tried to perform a running landing on the grass area next to the runway, so he aligned the aircraft to runway 19 to get wind from the left. However, when he applied right cyclic to align the aircraft, he might have unintentionally reduced the airspeed less than 80kt and the aircraft started spinning. At this moment the aircraft height was about 200ft, he had no option to descend and regain airspeed than to try to maintain horizontal spinning of the aircraft.

The investigation of this case confirmed that the spinning begins at the airspeed less than 80kt in level flight. On the other hand, the rotorcraft flight manual states that "*Touchdowns made into the wind between 20 and 30 KIAS, may provide good directional control at reduced power (collective) settings.*", however, detailed procedures to reach the touchdown is not stated. The manufacturer should illustrate the missing procedures.

3.8 Survival factors

The reason for occupants' escape from serious injuries and no post crash fire were considered to be attributed by the followings.

(1) The pilot knew the aircraft condition, confirmed to what extent he was able to control the aircraft and he never gave up controlling the aircraft until the last moment.

(2) Reduced aircraft weight by 1-hour fuel consumption flight and level attitude at the time of hard landing attributed crashworthiness design to work adequately, in which landing impact to the occupants was attenuated by landing gear, lower fuselage and crew seats progressively.

(3) Landing impact was attenuated by crashworthy fuel tanks themselves, resulting to neither rupture nor leak.

(4) Occupants retightened their safety belts and secured unsecured objects in the cabin.

4. Probable Cause

The probable cause of this accident is estimated that during flight, a T-T strap rupture in the fan assembly triggered the aircraft's loss of yaw control, making it difficult to control the aircraft during an attempted emergency landing, which resulted in an uncontrollable spin, a hard landing and substantial damage to the aircraft.

The probable cause of the rupture of a T-T strap is estimated that repetitive large compression and shear strain generated in the area where T-T strap composite material is closest to the edge of the spool, was not considered at the time of its design, lead to fatigue of the material from that area and degraded the strap's integrity.

5. Actions taken by the manufacturer and The Authorities

1. The manufacturer issued a SB (Service Bulletin)⁸ and Japanese authority (JCAB) issued a TCD (Technical Circular Directive) respectively on November 3, 2004 and May 6, 2005, to reduce the life limit of T-T straps with specific part numbers and to instruct method of inspection after being removed from the aircraft. 2. With regard to T-T straps' failure which caused MD900 accidents in the United States and Japan, the NTSB issued the following safety recommendations to the FAA on April 10, 2006 with reasons such as insufficient fatigue load spectrum used for testing for the FAA approval.

The FAA should:

(1) Make the manufacturer to conduct additional fatigue tests for T-T straps installed in the NOTAR fan of MacDonnell Douglas model 500N series, 600N, and MD900 helicopters, which includes load cases that cause shear or compression in the direction transversing reinforced fibers of the T-T straps.

(2) Based on existing data and additional data acquired during accomplishment of the tests mentioned in (1), take regulatory action to change the intervals of inspection and replacement of T-T straps installed in NOTAR fans of MacDonnell Douglas, model 500N series, 600N, and MD900 helicopters.

(3) Take actions to inspect T-T straps for layered fiber fractures and for longitudinal cracks using X-ray radiograph, if fractures or cracks are found, to remove the strap from service.

⁸ Technical bulletin released by aircraft or parts manufacturer to their users for the purpose of increased safety, performance and information input.

Figure 1 Estimated flight path

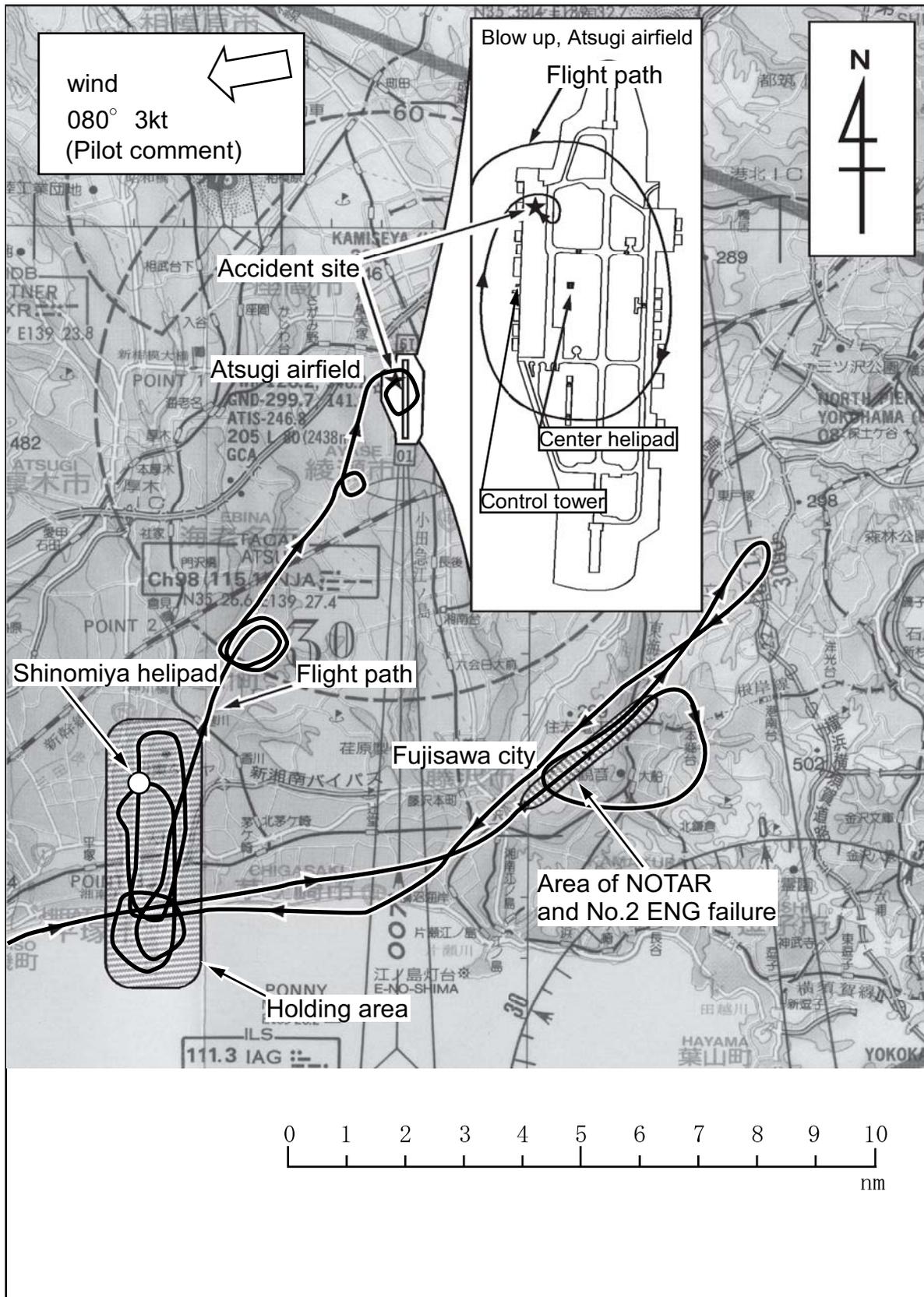
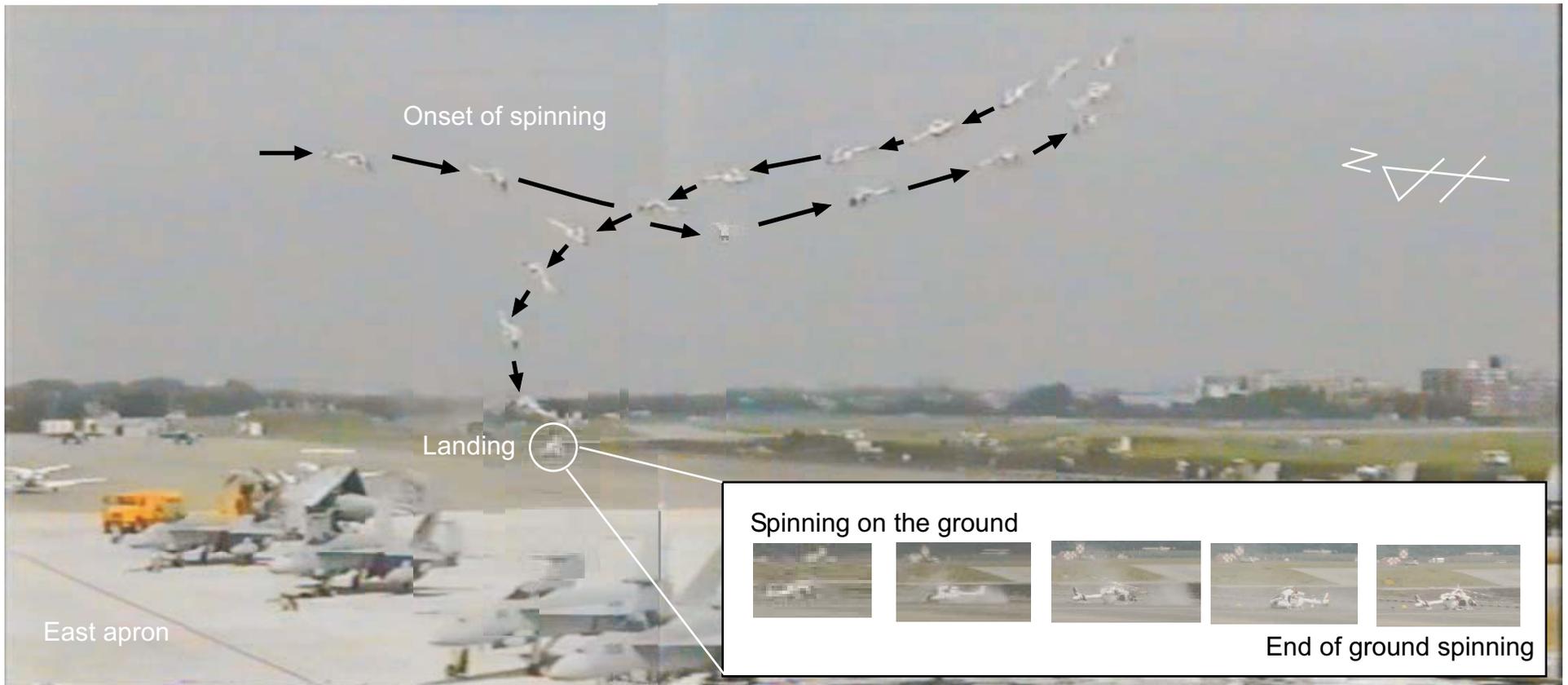


Figure 2 Aircraft spinning before/after landing



Generated out of video recording done at the control tower

Figure 3 Three -angle-view of McDonnell Douglas MD900

unit : m

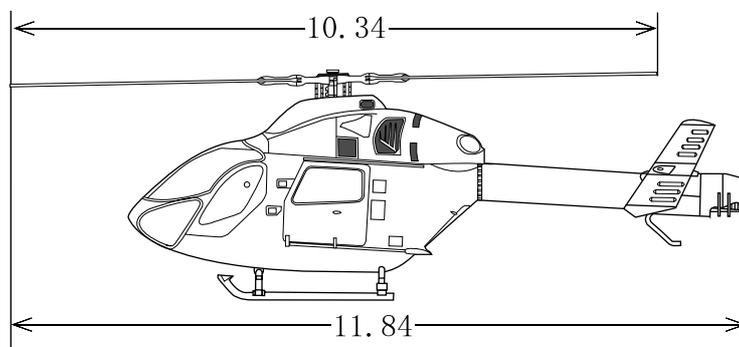
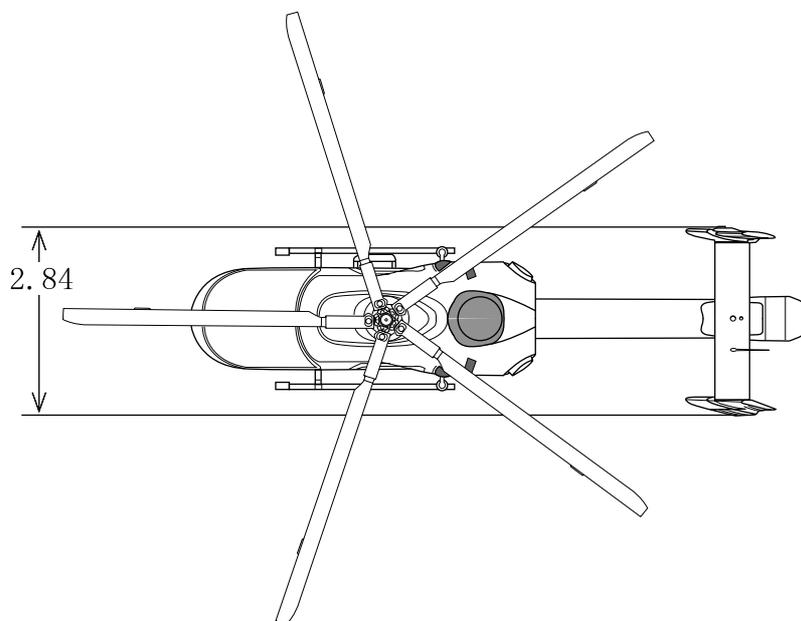
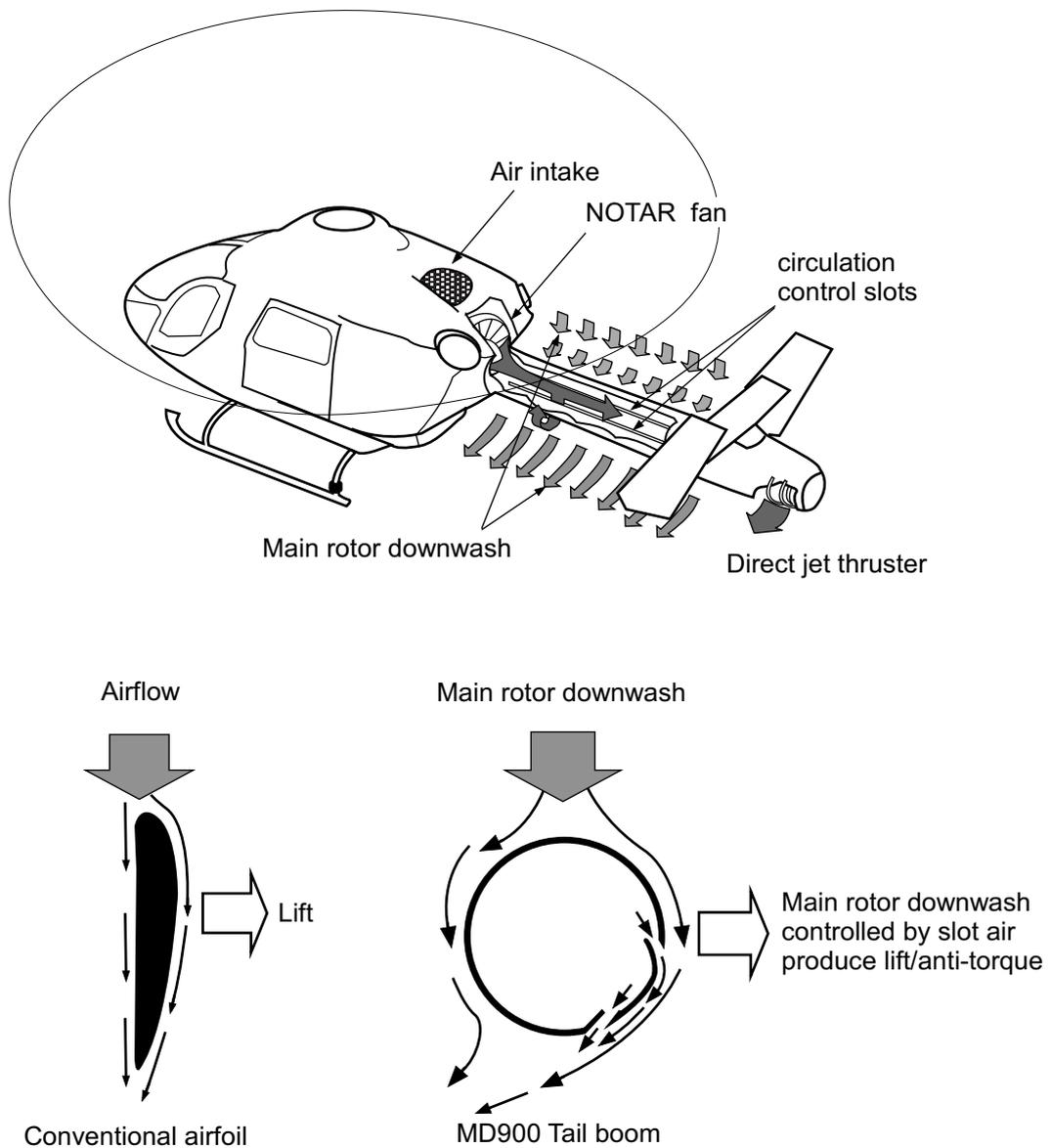


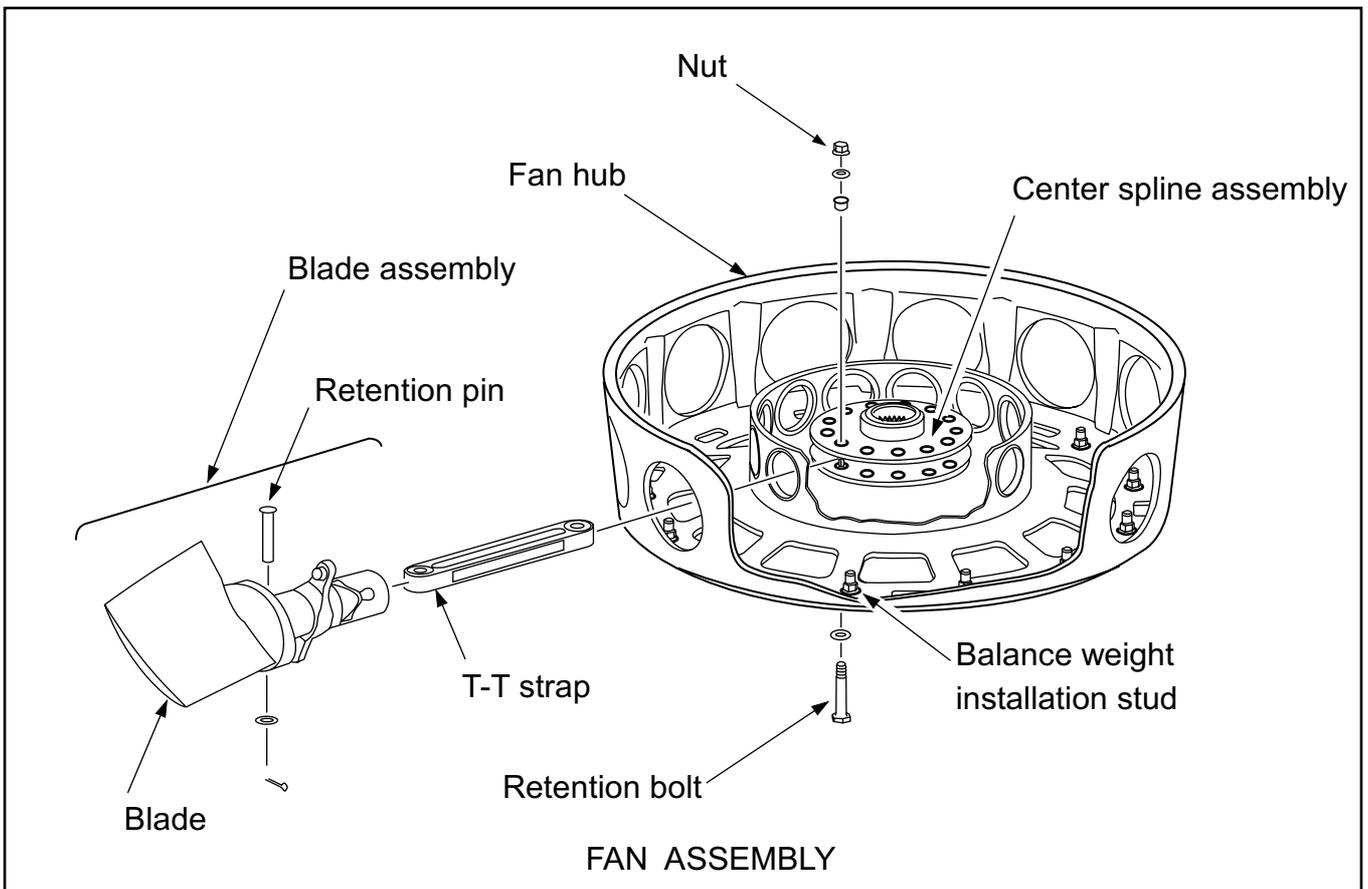
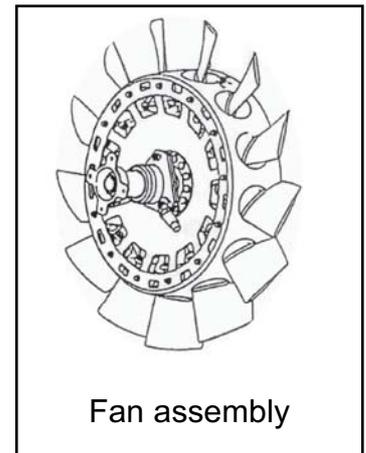
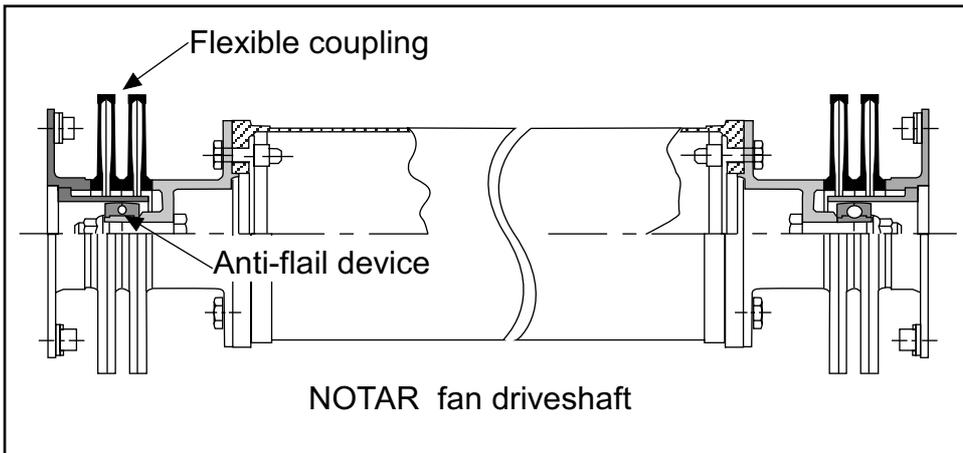
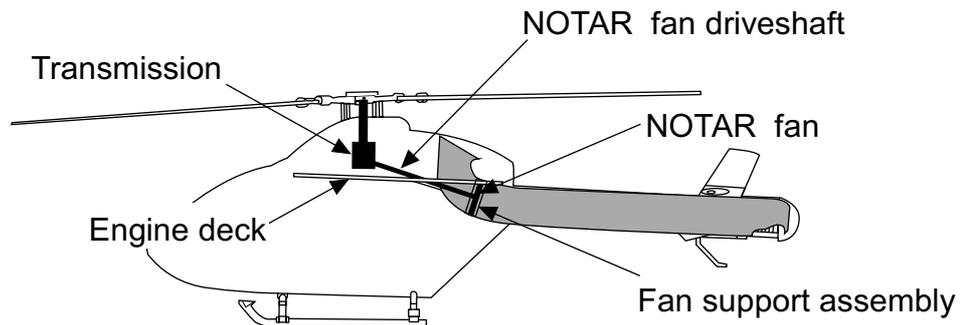
Figure 4 NOTAR system function

NOTAR fan housed in the aft fuselage pushes large amount of low pressured air into the tail boom. The air is released through slits cut in the starboard/right side of the tail boom and jet thruster. The air released through the slits flows along the tail boom surface by a boundary-layer control called Coanda effect. Under the effect of main rotor downwash, tail boom acts like a wing and produces lift toward right when observed from aft and this becomes a part of anti-torque. During hovering anti-torque is compensated for with thrust generated by jet thruster.



Generated with MD web site information

Figure 5 NOTAR fan assembly



These figures are generated based on the contents of MD900 Rotorcraft Maintenance Manual and MD900 Student Training Manual.

Picture 1 Accident helicopter



Picture 2 Damaged NOTAR fan

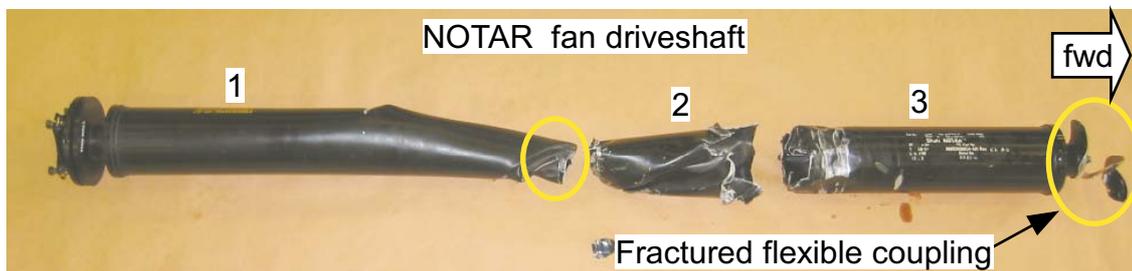
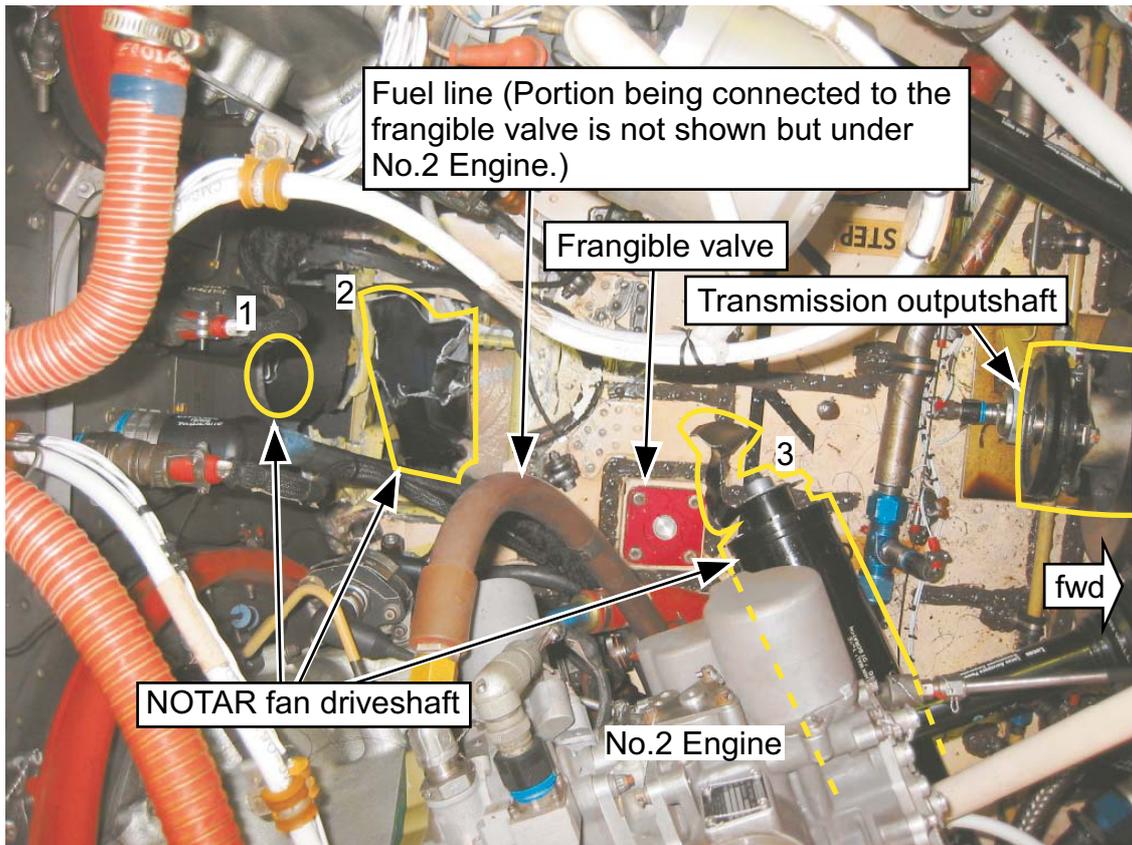


One blade assembly is missing due to fracture of the T-T strap

Picture 3 T-T strap



Picture 4 Engine deck



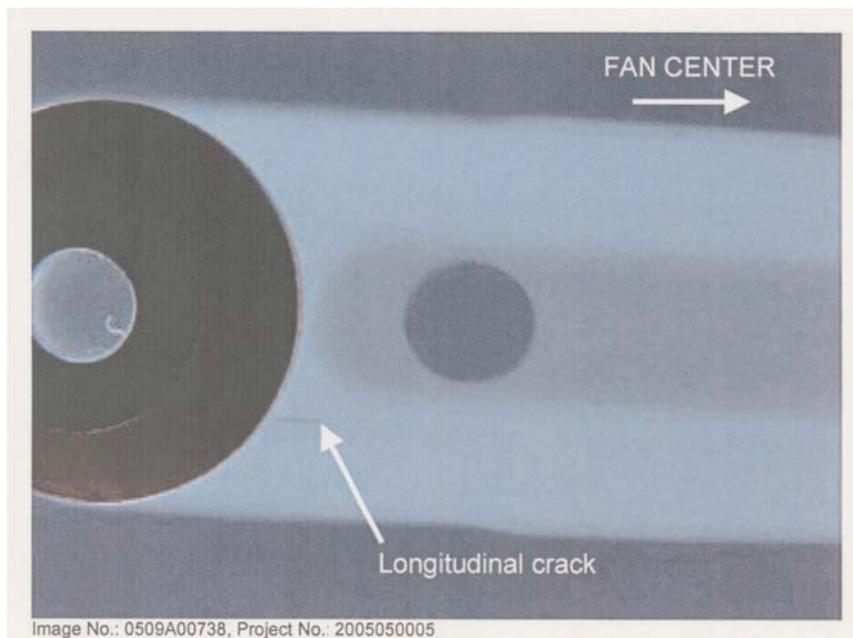
NOTAR fan driveshaft was fractured into three parts, 1,2 and 3. Part 1's fwd portion (circled area) is observable in the upper photo.

Attachment T-T strap close examination

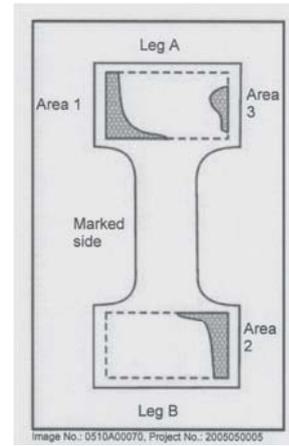
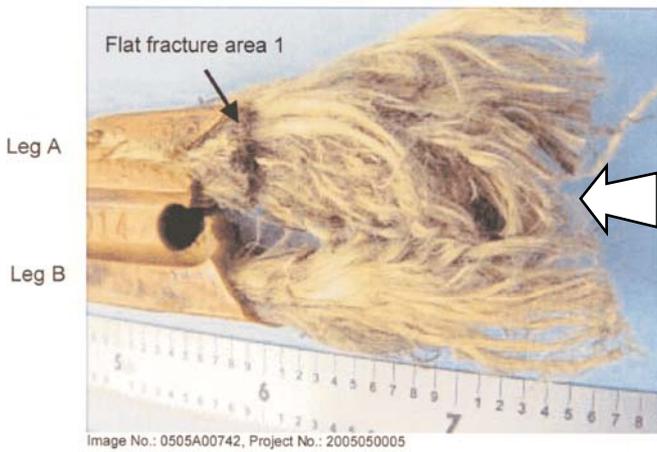
Pictures are reprinted from the NTSB Material Laboratory Factual Report, Report No. 05-103



Picture A Fractured T-T strap



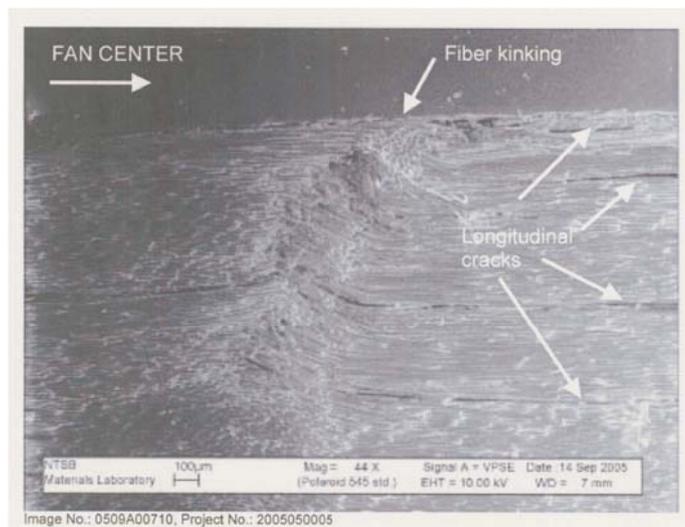
Picture B X-ray picture, fractured T-T strap



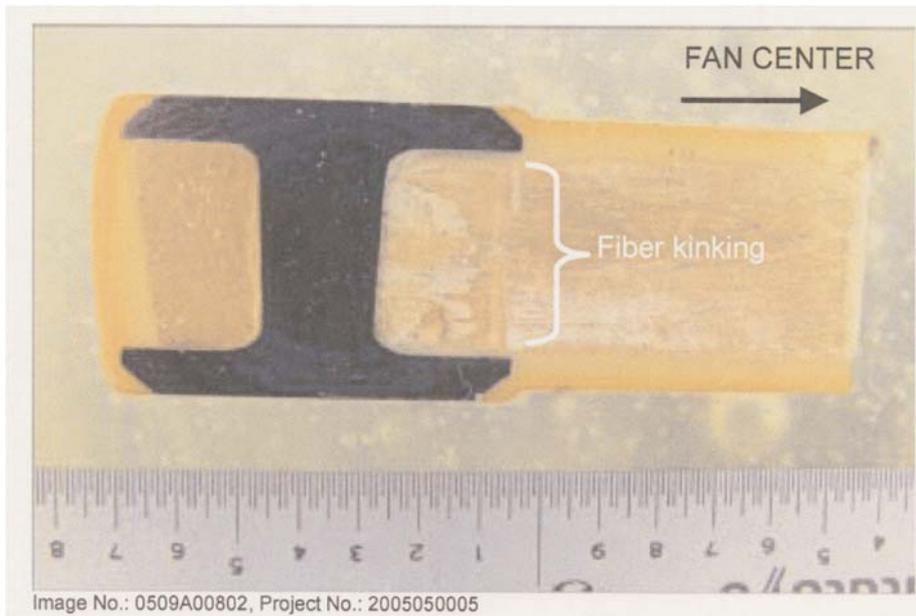
Picture C Closer view of the fractured fibers Schematic drawing of the strap fracture seen in the direction of arrow



Picture D Cross section in a plane nearly perpendicular to the spool axis



Picture E Close view of fiber kinking



Picture F Cross section in a plane parallel to the spool axis



Picture G Close view of fiber kinking