AA2008-8

AIRCRAFT ACCIDENT INVESTIGATION REPORT

TOHO AIR SERVICE CO., LTD.
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August 29, 2008

Aircraft and Railway Accidents Investigation Commission

The investigation for this report was conducted by Aircraft and Railway Accidents Investigation Commission, ARAIC, about the aircraft accident of TOHO AIR SERVICE, BELL 412 registration JA9991 in accordance with Aircraft and Railway Accidents Investigation Commission Establishment Law and Annex 13 to the Convention on International Civil Aviation for the purpose of determining causes of the aircraft accident and contributing to the prevention of accidents/incidents and not for the purpose of blaming responsibility of the accident.

This English version of this report has been published and translated by ARAIC to make its reading easier for English speaking people who are not familiar with Japanese. Although efforts are made to translate as accurately as possible, only the Japanese version is authentic. If there is any difference in the meaning of the texts between the Japanese and English versions, the text in the Japanese version prevails.

Norihiro Goto,
Chairman,
Aircraft and Railway Accidents Investigation Commission

AIRCRAFT ACCIDENT INVESTIGATION REPORT

TOHO AIR SERVICE CO., LTD.

BELL 412 (ROTORCRAFT)

JA9991

APPROXIMATELY 1.3KM NORTH OF NAKATSUGAWA

TEMPORARY HELIPAD, NAKATSUGAWA CITY

GIFU PREFECTURE

AROUND 15:39 JST, JUNE 2, 2007

July 18, 2008

Adopted by the Aircraft and Railway Accidents Investigation Commission

(Air Sub-committee)

Chairman Norihiro Goto

Member Yukio Kusuki

Member Shinsuke Endo

Member Noboru Toyooka

Member Yuki Shuto

Member Akiko Matsuo

1 PROCESS AND PROGRESS OF ACCIDENT INVESTIGATION

1.1 Summary of accident

On Saturday June 2, 2007, a Bell 412 operated by Toho Air Service Co.,Ltd., registration JA9991, after taking off from the Gifu-Nakatsugawa temporary helipad for the purpose of spreading aerial reforestation material from its slinging bucket onto the upper region of Ichinosawa ravine of Mt. Ena in Gifu Prefecture and being on a return flight, crashed into a mountain slope approximately 1.3km north of the temporary helipad around 15:39 Japan Standard Time (JST, UTC+9H)[1].

The pilot, sole occupant on board was fatally injured.

The aircraft was destroyed, but no post-crash fire broke out.

1.2 Outline of Accident Investigation

1.2.1 Investigation organization

On June 2, the Aircraft and Railway Accidents Investigation Commission (ARAIC) assigned an investigator-in-charge and two investigators for this accident. On June 29, the ARAIC assigned an Air Medical Doctor for this investigation.

1.2.2 Foreign representative

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

1.2.3 Implementation of investigation

June 3 - 4, 2007:	Investigation of the wreckage and the accident site and interviews
June 26 - July 2, 2007:	Investigation of wreckage and the accident site
July 4 - 9, 2007:	Investigation of wreckage and the accident site
July 24, 2007:	Investigation of wreckage
October 10, 2007:	Investigation of wreckage

1.2.4 Comments from parties relevant to the cause of the accident

Comments were taken from the party relevant to the cause of the accident. But comment was not taken from the PIC due to his decease.

1.2.5 Comments from participating state

Comments were invited from the participating state.

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

2 FACTUAL INFORMATION

2.1 History of flight

On Saturday June 2, 2007, a Bell 412 operated by Toho Air Service Co.,Ltd.(hereinafter referred to as "the Company"), registration JA9991 (hereinafter referred to as "the Aircraft"), took off from the Gifu-Nakatsugawa temporary helipad (hereinafter referred to as "the helipad") , with a pilot in command (PIC) as the sole occupant on board, for the purpose of aerial spreading of reforestation material onto the national forest on the southern slope of Mt. Ena. On a return flight after finishing the spreading, around 15:39 the aircraft crashed into a left slope of Ichinosawa ravine approximately 1.3km north of the helipad.

The circumstances from the occurrence of the accident to the discovery of the crashed aircraft were stated as follows by personnel working at the helipad, namely by a sales manager and a mechanic of the Company, and a site manager of the reforestation company which subcontracted with the Company to do the aerial work.

(1) Sales manager of the Company

On May 29 the Aircraft was ferried to the helipad and we started aerial reforestation flights on May 30. It was planned that the work would finish on June 2 if the weather was favorable and the days from June 3 to 5 were set apart for complement flights. The helipad was manned by the PIC, three mechanics and I, and by the site manager of the reforestation company and his workers.

The work was to spread the reforestation material "slurry", the mixture of plant seeds, fertilizer, water and starch from the slung bucket to the landslide-damaged slopes of the mountain. Slurry was prepared by the workers of the reforestation company.

In the morning of the accident day, we arrived at the helipad around 7 o'clock, had a meeting and did a preflight check and necessary preparation. The summary of the day's action was as follows and the day's total flight time was 5 hours and 26 minutes.

Time	Action	Duration (minutes)
07:48-07:52	Confirmation of spreading area	4
07:54-08:34	Aerial spreading 8 times	40
08:34-08:40	Refueling	6
08:40-09:32	Aerial spreading 12 times	52
09:32-09:39	Refueling	7
09:39-10:33	Aerial spreading 12 times	54
10:33-10:40	Refueling	7
10:40-11:16	Aerial spreading 8 times	36
11:16-12:40	Refueling, lunch and rest	84
12:40-13:26	Aerial spreading 10 times	46
13:26-13:31	Refueling	5
13:31-14:11	Aerial spreading 8 times	40

14:11-14:45	Refueling, an interruption of the work (Due to the malfunction of a slurry mixer.)	34
14:45-15:39	Aerial spreading 10 times	54

One of the mechanics, who was at the company radio, said that around 15:39 he heard a click noise generated by the pressing of a press-to-talk button.

We had three buckets and two of them were in use. While one was in use for spreading, the other was being loaded with slurry. When the helicopter came back, a mechanic released the link of the empty bucket from the hook at the bottom of the sling line, attached the link of loaded bucket. One circuit of aerial spreading took about 5 minutes from departure to return to the helipad.

A bucket weighs about 140kg and each amount of loaded slurry weighs about 700kg on average. The amount of the slurry was adjusted by the mark attached inside of the bucket. The weight of the last slurry was 380kg and this was measured by the onboard cargo hook load monitoring device.

The length between the cargo hook to the bottom of the bucket was 8.5m and the PIC maintained the bottom of the bucket away from the ground about 20 to 30m during his flight.

We had two company radios there and they were assigned to me and the mechanic. Just before the 67th landing I sent a message to the PIC saying "Next one is the last." His response was "Roger." When the Aircraft was stabilized after the 68th takeoff, I radioed to him saying "After this circuit, we'll have a confirmation flight." His response was "Roger."

The PIC was a man of self-control and he did not dare to take risks. His behavior on that day was nothing unusual.

(2) Mechanic

On the day of the accident, we arrived at the helipad around 7 o'clock and I did a preflight check. No anomalies were found with the Aircraft and I confirmed that the fuel remaining at that time was 600 lb. Refueling was made to the Aircraft six times that day. The PIC decided the amount of refueling by reading the cockpit fuel gauge, so mechanics knew only rough amount of each refueling.

While the Aircraft was in flight I was at the company radio. The PIC usually informed me of the time of refueling, for instance by saying "Request refueling two circuits away", however, there was no such advance notice before the last circuit (68th) of the day. The last circuit began at 15:35 and I am sure he knew that was the last one of the day because he said so on the radio. After the completion of the spreading, it was planned to refuel and to have a flight to confirm the day's result. The PIC's fuel management was made based on the remaining fuel shown on the fuel gauge.

Around 15:39 I heard a "click" noise from the radio and I called the PIC but there was no reply. Although the time passed beyond 15:40 there were no indications of the returning Aircraft. I asked to stop the slurry mixer and tried to listen for helicopter noise, but nothing was heard from Ichinosawa ravine.

When we had a break from 14:11 to 14:45 I chatted with the PIC. I found no unusual thing about him and he did not seem to be fatigued. It was drizzling a little then and the mountain tops were covered with fog.

While the Aircraft was making the last circuit the weather around the helipad was such that there was no cloud, wind was nearly calm, no visibility problem. It was cool so I guess the temperature was below 20°C.

(3) Site manager of the reforestation company

My company received a contract for the reforestation project and it was consigned to Toho Air Service Co.,Ltd.

Around 15:40, as the Aircraft did not come back, I walked to the place where I could see the last covered area but I saw no sign of the Aircraft. Although the mountain top was covered with cloud, the covered area was visible but no precipitation was observed there.

Just after 16 o'clock I departed the helipad with six workers and hiked up Ichinosawa ravine to search for the Aircraft. Hiking up the ravine was the only access to the covered area and I presumed the Aircraft would have made a forced landing somewhere in the ravine. Around 17 o'clock one of the workers found the crashed Aircraft on a mountain slope. At 17:13 the PIC was found near the fuselage still strapped in his seat.

The accident site (39° 25' 35"N, 137° 34' 39"E) is located on the left slope of Ichinosawa ravine about 1.3km north from the helipad. The accident occurred around 15:39. (See Figures 1, 2 and Pictures 1,2)

2.2 Injury to persons

The PIC was fatally injured.

2.3 Damage to the Aircraft

2.3.1 Degree of damage

The Aircraft was destroyed but no post crash fire broke out.

2.3.2 Aircraft damage by part

(1) Fuselage	Destroyed
(2) Skids	Destroyed
(3) Main rotor hubs and blades	Destroyed
(4) Transmission	Destroyed
(5) Engines	Damaged
(6) Tail boom	Destroyed
(7) Tail rotor blades	Destroyed
(8) Fuel tank	Damaged

2.4 Damage to other than the Aircraft

About ten trees were broken.

2.5 Personnel information

PIC: Male, age 66

Commercial Pilot Certificate (Rotorcraft)

Date of issue	February 28, 1967
Rating: Bell 212	March 11, 1981
Instrument rating(Rotorcraft)	February 13, 1990

Class 1 Airman Medical Certificate

End of validity	February 11, 2008
Total flight time	14,295 hours 03 minutes
Flight time, last 30 days	30 hours 40 minutes
Total flight time on Bell 412	1,571 hours 56 minutes
Flight time, last 30 days on Bell 412	28 hours 10 minutes

2.6 Aircraft Information

2.6.1 Aircraft

Type	Bell 412
Serial number	33181
Date of manufacture	September 24, 1989
Certificate of airworthiness	No. Tou-18-587
End of validity	March 9, 2008
Airworthiness category	Rotorcraft, Transport category A and B
Total time in service	3,727 hours 04 minutes
Time since last scheduled 600 hour maintenance check (February 20, 2007)	90 hours 34 minutes

(See Figure 3)

2.6.2 Engines

Type: Pratt and Whitney Canada PT6T-3B

	Serial No.	Date of manufacture	Total time in service
No.1	CP-PS63071	10-Mar-89	3,727 hr 04 min
No.2	CP-PS63072	10-Mar-89	3,727 hr 04 min

2.6.3 Weight and Balance

The weight of the Aircraft at the time of the accident was estimated to be approximately 7,922.3 lb, with the position of center of gravity at 138.7in aft of datum point in longitudinal axis and 0.6in right of longitudinal axis, both being within the allowable limits (cf. Maximum certificated weight is 11,900 lb. Allowable center of gravity range corresponding to the weight of 7,922.3 lb is between 130-144in aft of datum point in longitudinal axis and 4.5in L – 4.5in R of longitudinal axis.)

2.6.4 Fuel and lubricating oil

The fuel was JET A-1. Oil was Mobile Jet Oil 254.

2.7 Meteorological Information

According to the personnel at the helipad, the weather was as follows:
Cloudy with calm wind, good visibility and temperature of around 20°C

2.8 Communications

Communications over the company radio between the Aircraft and the helipad was technically normal.

2.9 Information on accident site and wreckage

2.9.1 Accident site

The accident site is located on the left slope of Ichinosawa ravine, which originates and extends south west from the top of Mt. Ena. The distance from the mountain top to the site is about 2.7km. Conifers and broadleaf trees more than 20m tall grow all over the area and the ground is covered with underbrush. The average slope inclination is about 45° and elevation is about 1,100m. About 100m upstream of the accident site lies a flat riverbed with a width of more than 20m.

The Aircraft rested on the slope about 17m from the ravine stream, orienting to north (upstream) with left side of its fuselage on the ground and suspended by trees from tumbling down the slope. The tail boom was oriented to the opposite direction of the fuselage and its horizontal stabilizers were placed under the fuselage. No fuel leak was confirmed.

Hereinafter debris locations are described with the location of the Aircraft's cargo hook as the datum point.

A beech tree stands 16m upstream and 22m upslope, its trunk was broken at a height of about 14m from the ground. Part of the broken trunk lied 1m downstream from the fuselage. Surrounding the beech tree, there were no slashed-away traces of tree canopies by rotating main rotor blades.

There is a 2m by 2m rock 8m upstream and 19m upslope. The rock had a scratch marks with blue paint that is identical with the Aircraft's lower fuselage paint. Left VOR antenna and debris of anti-collision light attached forward of the cargo hook were found upslope from the rock.

A cypress tree of about 20m tall, 5m upstream and 15m upslope, was pushed down downstream and the trunk was broken at a height of 10m from the ground. Upslope of this tree there was a 5.8m-long main rotor blade (Red[2]) (measured from the blade tip). At the root of the cypress, 40cm-long aft end of the left skid was found buried.
A 3.6m-long main rotor blade (Yellow) (measured from the blade tip) was found 8m upstream, 10m upslope.

Within about 3m radius of the point 10m upslope, many debris of cockpit switch panels, a part of left windshield, support arms of a cargo mirror and the like were found.

Battery was found disintegrated and scattered 10m downslope.

The bucket slung by the Aircraft was found on the slope about 60m north.

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[2] Main rotor blades are color coded with yellow, red, blue and green to distinguish with each other.

(See Figure 2 and Picture 2)

2.9.2 Detailed information of aircraft damage

(1) Fuselage: Forward fuselage ranging from nose to cockpit was crushed and destroyed evenly from the front. Cockpit was exposed. Left side of the fuselage ranging from left pilot seat to cabin and the aft lower fuselage up to tail boom attachment section were also substantially damaged.

(2) Landing gear: Forward and aft cross tubes attachment points to the fuselage were destroyed, but both cross tubes were not separated from the fuselage. Left and right skids were fractured into five pieces and four pieces respectively. Only aft-end of right skid remained attached.

(3) Main rotor blades: Red and Yellow blades were separated at the points 1.2m and 3.4m away from their roots respectively. Shreds of tree bark were found attached at respective separation points. Blue and Green blades were bent at the points 2.7m and 2.5m from their roots respectively. Leading edges of both blades showed no significant damage such as tree strikes.

(4) Transmission and mast: Transmission tilted slightly to the left due to the destruction of its fitting points to the fuselage. The mast was rotated without seizure and it had no damage. The swashplate was almost perpendicular to the mast, not showing inclination to any particular direction and was placed very close to its upper limit.

(5) Engines: Engine case, air intake and exhaust pipe of No.1 engine were deformed. The gas-producer turbine was rotated by hands without seizure. The power-turbine was stuck due to the deformation of its case.

No.2 engine's air intake and exhaust pipe were deformed. Gas-producer turbine and power-turbine was rotated by hands without seizure.

The output shaft of the combined gear box to which engine output shafts were connected was rotated by hands without seizure. Clutch mechanism did not have any anomalies.

Bypass doors of both particle separators in engine air intakes were closed.

(6) Tail boom: The tail boom was separated from the fuselage and its horizontal stabilizers were placed under the fuselage. Tail skid attachment point to the tail boom was broken. Underside of the tail skid exhibited no indication of contact with rocks or other objects.

(7) Leading edges of both tail rotor blades showed no damage. One of the blades' trailing edge had a collapse of 15cm by 15cm in cord/span-wise.

(8) Fuel tank consists of ten fuel cells. Of which, left upper cell's outboard skin was punctured at several points. Other cells including connecting pipes showed no cracks or damage.

(9) The bucket was empty. It had some dents which were caused when it landed on the ground. The cargo sling which slung the bucket was not snapped and the cargo hook had no trace of damage.

2.9.3 Indicator needle, switch and valve position

(1) Fuel gauge indication	Zero
(2) Collective lever	Pulled up exceeding upper stop position (lever attachment was damaged)
(3) Throttle	Full open
(4) Fuel cross-feed valve	Open
(5) Inter-connect valve	Open
(6) Bypass doors of particle separators	Closed (both engines)

(7) Fuel control panel

The panel was partially damaged by the crash. Some switch positions are considered to have been changed then. The switch positions for normal flights are shown in parenthesis.

a. Boost pump switches	No.1 Engine	OFF (ON)
	No.2 Engine	ON
b. Transfer pumps	No.1 Engine	OFF[3] (ON)
	No.2 Engine	ON
c. Fuel valve switches	No.1 Engine	ON
	No.2 Engine	ON
d. Cross-feed switch		NORM
e. Inter-connect switch		OVRD CLOSE[4] (NORM)
f. Particle separator switches		
	No.1 Engine	NORM
	No.2 Engine	OVRD ON[5] (NORM)

(See Figure 4)

2.10 Medical and pathological information

According to the autopsy report provided by Gifu Prefectural Police Headquarters, the cause of the PIC' death was traumatic shock due to numerous internal and external lesions including fractured bones and ruptured heart and other damages.

Alcohol and drug substance were not detected in the blood.

(See figure 2)

2.11 Information on search and rescue

The Company headquarters (Operations Department) received a call from the helipad at 15:45 to the effect that "The Aircraft has not returned even after the expected time of return." With this information the headquarters started internal collection of information and coordination for search operations using its own helicopter.

The Company headquarters reported to The Tokyo Rescue Coordination Center

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3 In OFF position, fuel transfer from No.1 cell to No.3 cell, to be stated in 2.12.2(1), does not take place.

4 In OVRD CLOSE position, lateral fuel equalization in No.3 cells does not take place.

5 This switch position is used during maintenance work to open a bypass door and it is not used during normal flight.

(hereinafter referred to as "The Tokyo RCC") stating, "The Aircraft took off from the helipad around 15:35, landing due in 5 minutes, has not returned." With this information Tokyo RCC began search and rescue services. The Company headquarters' notification of missing Aircraft and inquiry of the information on the Aircraft to Nakatsugawa police station were made at 17:15.

Sometime after 16 o'clock a party of seven persons headed by the site manager of the reforestation company began searching along Ichinosawa ravine. At 17 o'clock the Aircraft was found crashed on left slope of the ravine, and at 17:13 the PIC was found outside of the Aircraft still strapped in his seat. This information was reported to the Company headquarters at 17:34 and to Nakatsugawa police station at 17:40. The PIC was airlifted to the helipad by a Gifu prefectural police helicopter which arrived at the accident site at 18:35 and the PIC was declared dead there. The PIC was transported to Nakatsugawa police station by an ambulance operated by Nakatsugawa City Fire Department.

The Tokyo RCC terminated its search and rescue services at 18:55, after the reception of the information on the discovery of the missing Aircraft and the PIC at 18:25.

The Aircraft was not equipped with any ELT[6]s.

2.12 Other necessary information

2.12.1 Permissions related to Civil Aeronautics Law of Japan

Concerning flights for the aerial spreading of reforestation material, permissions were granted per article 79 (Takeoff and landing performed other than aerodrome), article 81 (Flight below minimum safe altitude) and notification was made per article 89 (Dropping objects from an Aircraft).

2.12.2 Fuel

(1) Fuel system

Fuel tank consists of ten elastic cells made of rubber cloth. Of which six are placed under the cabin floor and the remaining four are placed in the aft fuselage, higher than the aforementioned six cells.

Six cells (hereinafter referred to as "lower cells") are placed in two columns with three cells on either side (hereinafter referred to as No.1, No.2 and No.3 from fwd to aft). Of four cells in the aft fuselage (hereinafter referred to as "upper cells"), two are placed on the longitudinal axis of the Aircraft and the remaining two are placed laterally sandwiching them.

Upper cells and lower cells are connected and fuel is fed to left and right engine by electric boost pumps installed in the corresponding No.3 cells. In order to maintain balance, fuel is designed to be consumed in the following sequence; about a quarter of upper cells, No.2 cells, half of the remaining of upper cells, No.1 cells, remaining of upper cells, and lastly No.3 cells.

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[6] This stands for Emergency Locator Transmitter. This radio installed in an aircraft emits distinctive signals to locate downed aircraft. An ocean type ELT is activated by throwing it in the water while automatic type ELT is activated by impact.

With the INTERCONNECT switch placed in NORM position, when the upper cells become empty, FUEL LOW caution light illuminates by the signal from the upper cells, and the interconnect valve opens to equalize fuel levels of No.3 cells. Each boost pump has a pressure switch. When either boost pressure is lost due to boost pump failure or other reasons, signal is sent to the cross-feed valve. The cross-feed valve is usually in closed position. When the CROSS FEED switch is placed in NORM position, an electric motor opens the cross-feed valve to send fuel from opposite fuel cell to both engines.

The structure of the interconnect valve and the cross-feed valve do not allow external shock to easily change the valve position and they maintain their valve positions when they lose electric power.

(See Figure 4)

(2) Fuel related description in the Rotorcraft Flight Manual (Extract)

a. *Unusable fuel: 26.5 ℓ* (46.7lb)

b. The FUEL LOW caution light illumination

fuel level in left or right cells at or below 190 lb.

c. Emergency procedure for FUEL LOW light illumination

(a). Less than 100 lb difference between No.1 and No.2 fuel quantities (Fuel level in left or right cells at or below 190 lb): plan landing.

(b). 100 lb or more difference between No.1 and No.2 fuel quantities (Possible fuel leak in cells with lower quantity): FUEL INTCON – OVRD CLOSE. Land as soon as possible.

(3) Fuel consumption rate

a. The company was operating the Aircraft with the presumed fuel consumption rate (FCR) of 700 lb/h.

b. The FCR was obtained from the charts. Conditions during aerial reforestation flight were set as follows.

(a) One circuit flight requires 5 minutes (3 minutes from takeoff to spreading, and 2 minutes for returning to the helipad). Maximum continuous power is applied for the first 3 minutes.

(b) Takeoff weight is 10,060 lb (including 1,540 lb (700kg) of slurry and 600 lb of fuel)

(c) The fuel flow charts which best correspond to the conditions near the accident site were used. (For pressure altitude of 4,000ft ,Outside Air Temperature (OAT) 7°C /27°C, and for pressure altitude of 6,000ft, OAT 3°C /23°C)

The average FCR is calculated to be 663.0 lb/h.

c. Actual FCR

When 600 lb of fuel remained previous day was taken into account, the actual FCR was calculated ((2,919+600)/326 x 60) to be 647.7 lb/h.

(4) Fuel gauge indication and its calibration

The Aircraft's fuel gauge consists of two needles and one digital window. Fuel quantity is indicated in "lb". Each needle indicates fuel quantity in the corresponding side of tanks and the digital window indicates total fuel quantity.

The maintenance manual does not contain periodical calibration of a fuel gauge.

The maintenance work on the fuel gauge related parts are done by way of on-condition basis and in case of malfunction, applicable parts are replaced. But the Aircraft had no history of replacements of fuel transmitters, indicators or signal conditioners. When a mechanic was on board, he checked the fuel gauge indications, however, there were no anomalies confirmed. There were no anomaly reports about the fuel gauge indication from pilots either.

(5) Fuel quantity retrieved from the Aircraft

7.9 ℓ of fuel in total was retrieved from the fuel cells. When the Aircraft was airlifted from the accident site to the helipad, small amount of fuel leaked from the left No.2 cell.

The Aircraft was left on the accident site for about a month before it was retrieved from the site, some amount of fuel is supposed to have evaporated. For this reason the amount of fuel contained in fuel control unit was not checked.

(6) Fuel amount supplied to the Aircraft on the day of the accident

The amount of fuel consumed at the helipad on June 2nd and 3rd was 3,978 lb known from the remaining fuel stored in oil drums. Of which 706 lb and 353 lb of fuel was serviced to an Aerospatial 350 and an Aerospatial SA315B respectively. The former flew to the helipad to take photos of the aerial reforestation, and the latter was to search for the Aircraft after the accident. The remaining 2,919 lb of fuel were serviced to the Aircraft.

(7) The PIC's advice to his younger colleagues

The PIC advised his younger colleagues to refuel the Aircraft before its remaining fuel reduces to 200 lb.

2.12.3 Particle separator

A particle separator is installed in an engine air inlet fairing in order to prevent foreign objects from being sucked into an engine during operation. A bypass door at the rear end of the particle separator opens to the exhaust pipe. It opens during engine start-up and closes during engine shutdown. The bypass door is closed while the revolutional speed of the gas-producer turbine is below 53±2% and incoming air and foreign objects are drawn into the engine. When it exceeds 53±2% the door opens. Foreign objects, with their inertia and negative pressure by the exhaust gas, bypass the engine and air alone is sucked into the engine. It takes about 10 seconds for a door to move between full open and full close. The power source of the door is DC essential bus and the bus is connected to a starter/generator and a battery.

The bypass door's structure does not allow external shocks to change its position and it maintains its position when it loses electric power.

(See Figure 5)

2.12.4 Idling speed of revolution of gas producer turbine

The gas producer turbine's idling revolutional speed is 61%. If it decreases below this value the engine stops.

2.12.5 Onboard fuel quantity for cargo flight

The maximum weight for 60ft out-of-ground-effect hovering using takeoff power is calculated to be about 11,300 lb from the flight manual under the conditions of 20ºC OAT at an elevation of 4,000ft. When the weight of the airframe, the PIC, the bucket and slurry is deducted from the maximum weight, it remains about 1,835 lb for onboard fuel, equivalent to 2 hours and 35 minutes of flight with FCR of 700 lb/h.

A Company personnel in charge of the operations stated that "With this gross weight, the engine torque and inter-turbine-temperature rise very close to their limits resulting in insufficient safety margin for engine operation. So we have to reduce either fuel or cargo. During the operations in Mt. Ena, the former method was chosen; slurry weight per lift was unchanged while fuel quantity was reduced to as little as 600 lb to attain safety margin. The latter method was not applied in Mt. Ena case, however, reduction of cargo weight may be chosen to extend flight time."

2.12.6 FUEL LOW caution light illumination time

The table below[7] shows FUEL LOW caution light illumination times for typical types of helicopters (the Aircraft inclusive) owned by the Company. They are the results of calculation with 1-hour fuel using the Company's standard FCR for each type. For the FCR of the Aircraft, 700 lb/h was used.

Aircraft Type	Fuel Consumption Rate	Time	Fuel remaining	Time to fuel starvation
AS350B	170ℓ/hr	39min	60ℓ	21min
AS350B2	170ℓ/hr	39min	60ℓ	21min
AS355N	110ℓ/hr x 2	37min	87.6ℓ	23min
EC135T2	110ℓ/hr x 2	37min	85ℓ	23min
BELL412 (the Aircraft)	397ℓ/hr	27min	215ℓ	33min

The table above shows that in a flight with 1-hour fuel, the Aircraft's FUEL LOW caution light illuminates sooner than others, and flight time until the fuel starvation after the illumination is relatively long.

2.12.7 PIC information and his working condition

The sales manager and the mechanic of the Company stated that the PIC was in good health condition and did not have any personal mental distress.

The Company's operations manual stipulates that a transportation business captain shall not work more than 12 consecutive hours or fly more than 8 hours a day.

[7] In the case of AS350B2, AS355N and EC135T2, each rotorcraft operating manual (ROM) gives 18 minutes, 18 minutes, 8 minutes respectively as duration until fuel starvation calculated at maximum continuous power. However, for easy comparison with the Bell 412, they are recalculated with normal fuel consumption rate. In the case of AS350B the ROM gives 25 minutes, however, calculation was made assuming the flight was made with normal fuel consumption rate.

The PIC's daily work hours and activities in the last one week are listed below.

Date	Actions	Flight hours
May 24	Ferry (Chofu to Gumma helipad)	25 min.
May 25	Day off	
May 26	Day off	
May 27	Ferry (to Akiyamago helipad) Cargo transport	30 min 1 hr 25 min
May 28	Cargo transport	4 hr 25 min
May 29	Test flight Cargo transport Ferry to the helipad	10 min 45 min 1 hr 50 min
May 30	Investigation flight Aerial reforestation flights (10 circuits)	25 min 45 min
May 31	Aerial reforestation flights (21 circuits)	1 hr 45 min
June 1	Aerial reforestation flights (75 circuits)	5 hr 10 min
June 2	Confirmation flight Aerial reforestation flights (68 circuits)	4 min 5 hs 22 min

2.12.8 ELT installation on rotorcraft

The Civil Aviation Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Japan issued guidance in July 1992, to encourage ELT installation on rotorcraft flying in the mountainous area.

3. Analysis

3.1 The PIC had proper airman certificate and valid airman medical certificate in accordance with applicable regulations.

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

3.3 Relations with weather conditions

Judging from the weather condition described in 2.7 and the statement by the reforestation company's site manager saying that there was no precipitation in the covered area when he observed, it is considered very likely that the weather condition had no bearing on the accident.

3.4 Engine

It is considered very likely that both engines had no anomalies except that No.1 engine power turbine was seized due to its case deformation.

As described in 2.9.2(5), the bypass doors of both particle separators were closed. Also as described in 2.12.3, the bypass doors need DC power to open/close. However as the battery was found detached from the fuselage, bypass door closure after the crash is very unlikely. Thus it is considered very likely that the bypass doors were closed in flight, meaning that revolutional speed of gas producer turbine of both engines went below 53±2%. Given the fact that this figure is below 61% (the figure described in 2.12.4), it is estimated very likely that both engines stopped in flight.

3.5 Fuel

(1) Change in fuel quantity

As described in 2.12.2(6), 2,919lb of fuel was serviced to the Aircraft on the day of the accident. Assuming the FCR of the Aircraft as 700 lb/h as described in 2.12.2(3), necessary fuel quantity for the flight of 282 minutes (44 minutes of flight until the day's first refueling subtracted from the day's total of 326 minutes) was calculated to be 3,290lb, larger than the consumed amount by 371 lb. This is because the Company's standard FCR of 700 lb/h includes a safety margin.

When the actual FCR of 647.7 lb/h shown in 2.12.2(3) c. is compared with the FCR of 663.0 lb/h obtained from the chart described in 2.12.2(3) b., the latter is bigger. This is considered to be the result of the calculation which was made based on the charts for 7°C and 27°C as the chart for 20°C was not available and that extrapolation was made as those charts did not provide FCR data for the speed below 60kt.

The table below is produced by calculating change in fuel amount on board based on the total fuel serviced to the Aircraft from oil drums, duration of refueling pump operation, actual FCR and flight duration. The duration of refueling pump operation was obtained by subtracting one minute, for a time to connect/disconnect the refueling pipe to the Aircraft, from the duration of refueling stated by the site manager of the Company in 2.1(1), so it contains some margin of error. The 5th and 7th refueling times were assumed to be six minutes as the average of refueling times up to then, due to no availability of statements on them. Time up to illumination of caution light means the time elapsed after the start of a flight.

Flights	1	2	3	4	5	6	7	Total fuel loaded on the day
Fuel carried over from previous flight (lb)	600.0	125.5	35.4	18.0	194.7	169.4	114.6	
Duration of refueling pump operation (min.)	0	5	6	6	5	4	5	
Fuel loaded before the flight (lb)	0.0	470.8	565.0	565.0	470.8	376.6	470.8	2,919.0
Total fuel on board before the flight (lb)	600.0	596.3	600.4	583.0	665.5	546.0	585.4	
Flight time (min.)	44	52	54	36	46	40	54	
Fuel consumed (lb)	474.5	560.8	582.4	388.3	496.1	431.4	582.4	
Fuel remaining after the flight (lb)	125.5	35.4	18.0	194.7	169.4	114.6	3.0	
Time up to illumination of caution light (min.)	20.4	20.1	20.4	18.8	26.5	15.4	19.1	

In this table, amount of fuel remaining after the first flight is considered to be almost accurate because it is based on the confirmed amount of carried-over fuel. Each remaining fuel at the end of each flight is obtained from recorded flight times and refueling pump operation times.

(2) Possibilities of fuel starvation

From the above-mentioned (1), it is considered that the PIC made refueling each time to have about 600 lb of fuel on board. The fuel remaining after the third flight is shown as 18 lb. In light of actual FCR of 647.7 lb/h, this amount of fuel corresponds to 1 minute 40 seconds of flight, and the Aircraft is considered to have narrowly escaped fuel starvation.

On the other hand, because the cross-feed valve was open as described in 2.9.3(4), it is considered probable that the Aircraft was flying in the condition that fuel in either tank was depleted just before the accident. It is considered very likely that both engines stopped as described in 3.4, and it was caused by fuel starvation judging from the change in fuel amount and the opened cross-feed valve.

(3) Time of FUEL LOW caution light illumination

The accuracy of fuel gauge is unknown because no calibration was made. However as described in 2.12.2(4) there were no records of replacement for fuel gauge related parts or no confirmed malfunction by pilots or mechanics, fuel indication was not considered to have any malfunction. During flights for the day, it is considered probable that FUEL LOW caution light illuminated 15 to 25 minutes into every flight.

(4) Retrieved fuel

As described in 2.12.2(5), 7.9 ℓ of fuel was retrieved from the fuel cells of the Aircraft after the accident. The amount of fuel leaked at the helipad is considered to be as much as 2 ℓ judging from the area of wetted ground. If the complete retrieval had been made, total amount is estimated to be around 10 ℓ. It is considered that this amount includes unusable fuel.

3.6 Effects of fatigue

The PIC flew the Aircraft for 5 hours and 26 minutes on the day. He rested for about one and half hours during lunch break and for 30 minutes during 2 o'clock intermission, and rested 5-10 minute during each refueling period. The mechanic stated, "The PIC did not seem to be fatigued."

It is considered probable that the weather condition did not demand the PIC psychologically stressed flights. On the other hand, considering his age and his flight time exceeding 5 hours per day, probabilities exist that his fatigue accumulated during the last flight, however, his fatigue or its influence on him was not made clear.

3.7 Reaction to the illuminated FUEL LOW caution light

As described in 3.5, it is considered probable that it was almost common practice for the PIC to fly with the FUEL LOW caution light illuminated for fairly long time until next refueling during aerial reforestation, and furthermore each flight ended with fuel remaining less than 200 lb (the figure described in 2.12.2 (7)).

If the PIC notices the caution light illumination, he has to confirm whether the difference between left and right fuel gauge indications is less than 100 lb or more than 100 lb. According to the calculation for the 7th flight, the caution light illuminates 19 minutes into the flight. Given the facts that the Aircraft continued its flight and the interconnect valve was open, it is considered very likely that the difference was in the former condition.

But it is considered probable that the PIC continued flying because he judged that he could fly some amount of time before fuel starvation and this was the same old practice. Judging from the table shown in 3.5, the PIC flew more than 50 minutes with almost the same amount of fuel as he did on the 2nd and 3rd flight of the day. So it is considered possible that the PIC's judgment like "One more circuit is possible," or his desire like "I want to put an end to the work with one more circuit" affected his decision making.

The only suitable open space along the ravine for autorotation landing along the route was, as described in 2.9.1, fairly flat riverbed wider than 20m which lies about 100m upstream of the crash site. As the Aircraft was found crashed on the slope with inclination of 45° after flying by the riverbed, it is considered possible that the PIC's awareness of the unexpected event and engine stop took place almost at the same time.

Given the facts that his method of fuel management was based on the remaining amount indicated on the fuel gauge and he did not mention next refueling to the mechanic over the radio, it is considered possible that by repeating circuit flights all by himself, the awareness on depleting fuel slipped from the his mind and the Aircraft fell into the fuel-starved condition.

As the table in 2.12.6 shows, the Aircraft has longer duration between the illumination of FUEL LOW caution light and fuel starvation, it is considered possible that this lengthiness contributed to the degradation of the PIC's awareness for the fuel management.

3.8 Autorotation

Given the fact that the combined gearbox and main transmission were confirmed seizure-free, it is considered very likely that the engine output was transmitted to main rotors.

Also with no anomalies in clutch mechanism it is considered that autorotation maneuver was possible.

As the swashplate was almost perpendicular to the mast, not tilting to any particular direction and was placed close to the upper limit, and the bucket was jettisoned upstream of the accident site, it is considered very likely that the autorotation descent was made.

However, considering the fact that the Aircraft crashed on a slope, altitude above the ground at the time of engines' stop was not high enough to perform autorotation descent. It is considered probable that pulling up the collective lever was not made after a steady autorotation descent as a part of the procedures but it was done instinctively instant before the contact with the trees.

3.9 Main rotor revolutional speed and the Aircraft's speed an instant before the crash

Because of the following reasons, it is considered probable that main rotor revolutional speed was low and the Aircraft's speed was almost null at the time of its first contact with the beech tree.

(1) If the main rotor was rotating at high speed, there should have been slashed trees in the neighborhood of the beech tree and trees upstream. There were no signs of slashing.

(2) The beech tree and the cypress tree were struck, judging from the main rotors' rotational direction, by the Yellow blade and the Red blade respectively. They were not torn away and found near the respective trees in a big assemblage. Remaining two blades were not separated, and each blade's leading edge had no trace of tree contact.

(3) The Aircraft, after pushing down the cypress tree downstream, advanced only 5m.

(4) The swashplate was pushed up close to the upper limit.

3.10 Crash sequence of the Aircraft

It is considered probable that the crash sequence, from the engines' stop to the halt of the Aircraft on the slope, developed as follows.

While flying over the east slope of the Ichinosawa ravine returning to the helipad, both engines stopped due to fuel starvation. The Aircraft started descent for autorotation landing and for the safety's sake it jettisoned the bucket. Before colliding with trees air speed reduction maneuver was made, the collective lever was pulled up and rotor revolutional speed dwindled. The Yellow blade was separated when it hit the beech tree followed by the Red blade separation upon contact with the cypress tree. Then the Aircraft sat astride on the trunk of the cypress tree, pushed it down, and the Aircraft slid rearward and landed on the ground from the aft fuselage. Upon falling the tail boom was disconnected from the fuselage. Then the Aircraft rolled to the right, made complicated movements, and finally halted on the slope blocked by trees with its nose orienting upstream.

While fragments of the beech tree are found flown to the neighborhood of the fuselage, the fragments of cypress tree are found near the cypress tree. It is considered probable that main rotor's rotational energy was nearly absorbed when it hit the former. Judging from the fact that a nose cowling stabbed with a beech tree fragment was found near the fuselage, and a part of fuselage ranging from nose to cockpit was evenly destroyed, it is considered probable that the destruction from nose to the cockpit was caused by hitting the beech and the cypress trees followed by tumbling down the slope in complicated movements.

3.11 Fuel management

This accident occurred to a type of aircraft whose FUEL LOW caution light illuminates sooner when it was operated for about an hour for short distance shuttle cargo transportation with the PIC as a sole crewmember. The Aircraft was in a circumstance where reduction of its maximum weight was necessary to secure engine's operational safety margin.

There are two options to reduce maximum weight; reduction of payload or reduction of fuel quantities. The latter has two sub-options.

(1) Having fuel quantities with the intention of flying some time after the illumination of the FUEL LOW caution light; or

(2) Having fuel quantities with the intention of completing planned flight before the illumination of FUEL LOW caution light.

It is considered probable that the method of fuel management applied to the Aircraft was above mentioned (1) to pursue the efficiency.

Even a type of aircraft whose endurance after the illumination of FUEL LOW caution light is long and urgent action to land is not required, it should be operated in a manner where efforts are made not to illuminate the caution light in principle.

On the other hand, the PIC is the ultimate person who determines when fuel servicing should be made. In this accident, only the PIC knew the exact amount of fuel loaded and the time of FUEL LOW caution light illumination. A fuel management procedure should be developed and strictly enforced, in which information is shared not only by a PIC but also mechanics and others and they are actively involved in the support of a solo flying PIC.

3.12 Reaction to emergency situation

As described in 2.11, the Company reported The TOKYO RCC of its missing aircraft 46 minutes after the occurrence of the accident, and to Nakatsugawa police station 1 hour and 36 minutes after the occurrence. It is considered probable that this delay was caused by the intra-company activities which include information gathering and search operations. In this accident it is considered that nonexistence of eyewitness and the accident site's characteristics of being in the steep mountains probably put the Company in difficult situation to collect information, however, the initial notification to the Search and Rescue Organization should have been made as soon as possible, keeping pace with the information gathering and establishing post accident emergency posture.

(intentionally left blank)

4. Probable Cause

In this accident the Aircraft, on its way back to the helipad after spreading reforestation material over the slope, crashed into the mountain, killing the PIC and was substantially destroyed.

It is considered very likely that the in-flight fuel starvation occurred because the fuel management was not done in such manner where the time of FUEL LOW caution light illumination was used as a reference to secure minimum fuel to allow safe landing, and the PIC did not get refueling while sufficient fuel was remaining after the light illumination. Probable contributing factors are efficiency prioritized operation, PIC's psychology to put an end to the work, and non-participation in fuel management by persons other than PIC conducting single crew operations.

(intentionally left blank)

5. Matters for reference

1. Following the accident the Company revised “Standard for Airlift Operations (TSOP 2-2-001)” on June 8, 2007 by adding the following contents.

(1) A pilot shall inform a mechanic and others of onboard fuel amount when he starts (resumes) the work or when refueled. The informed mechanic shall enter the amount of added fuel and fuel on board in such document as Cargo Transportation Record.

(2) When FUEL LOW caution light illuminates during flights, a pilot shall inform a ground (on-board) mechanic and others of the fact to share the information. The informed person shall enter the time and amount of fuel remaining in Cargo Transportation Record.

2. In accordance with the amendment of the ICAO annex which stipulates the international standard for onboard emergency locator transmitter (ELT) and its enforcement on and after July 1, 2008, the Civil Aviation Bureau, the Ministry of Land, Infrastructure, Transport and Tourism, amended the Civil Aeronautics Regulations to make it mandatory even for a rotorcraft to be equipped with one automatic ELT regardless of flying over water. The amended regulations became effective on July 1, 2008.

Figure 1 Estimated Flight Route

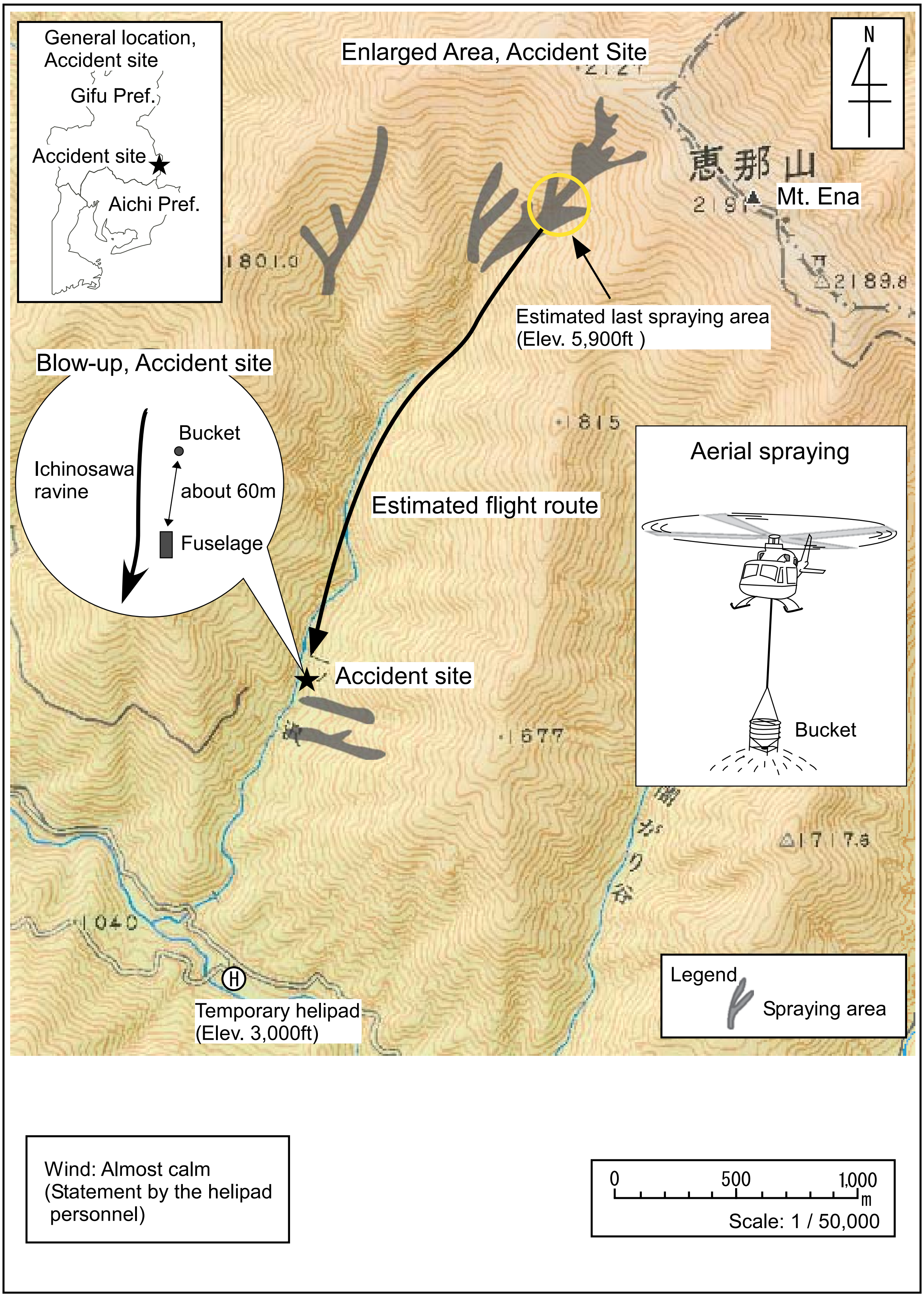


Figure 2 Accident Site

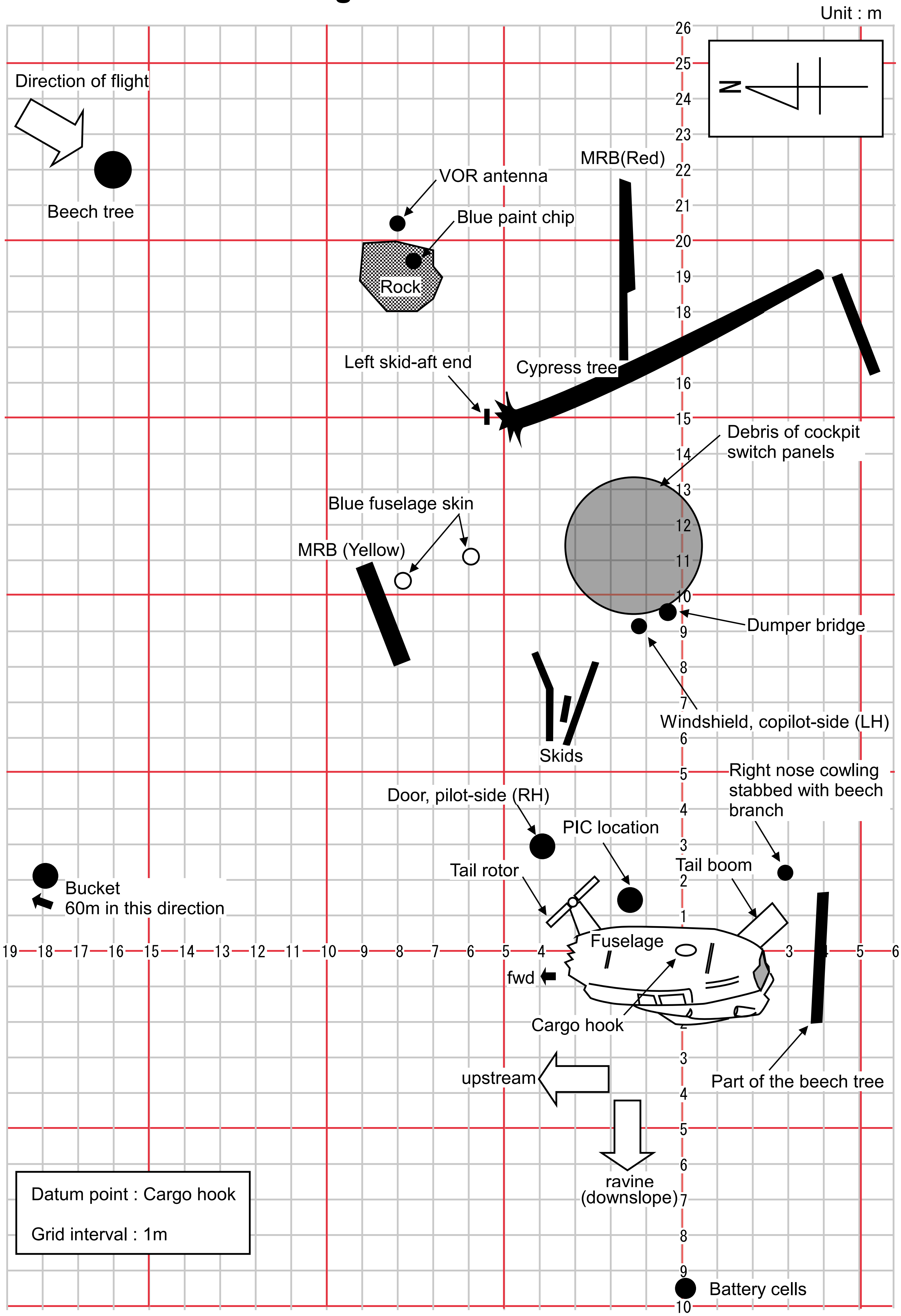


Figure 3 Three-angle-view of Bell 412

Unit : m

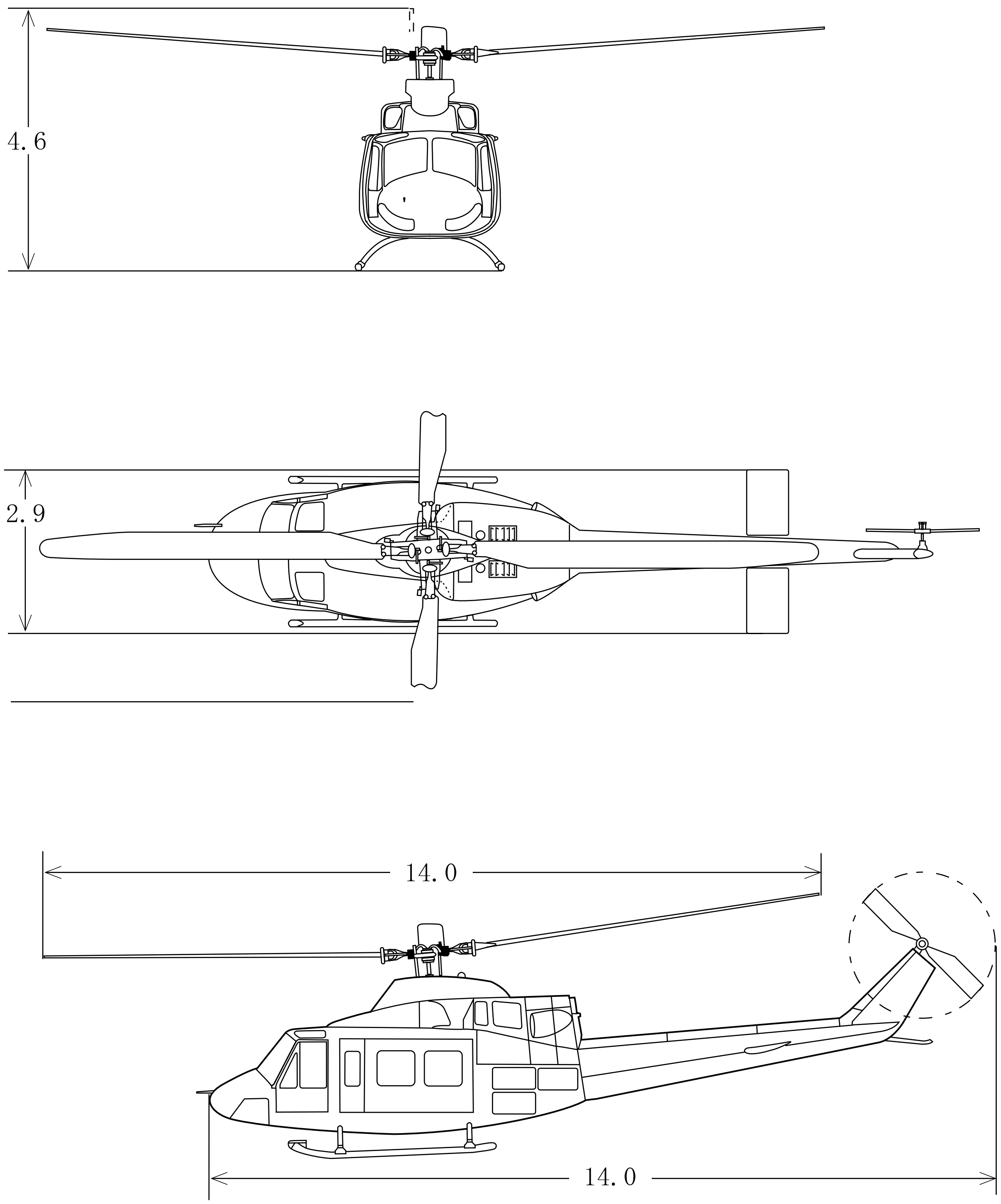
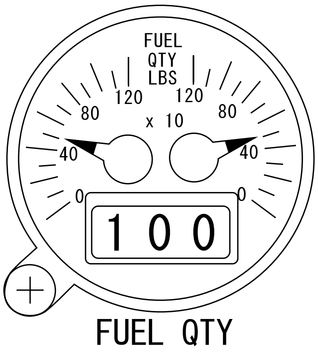


Figure 4 Fuel System

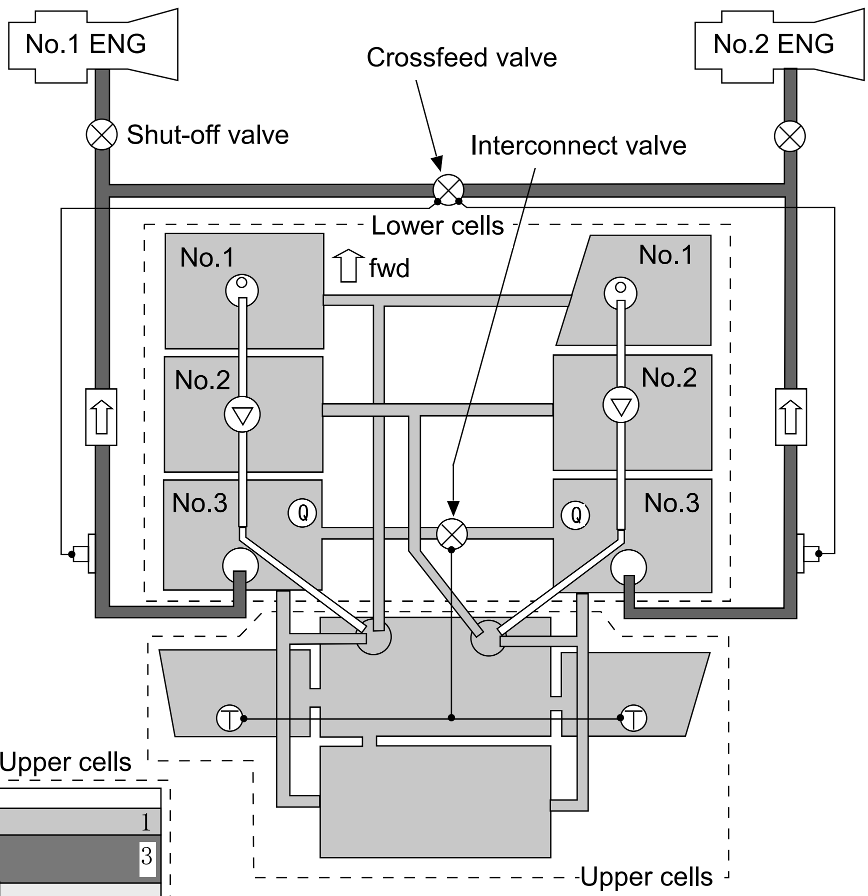


Fuel guage

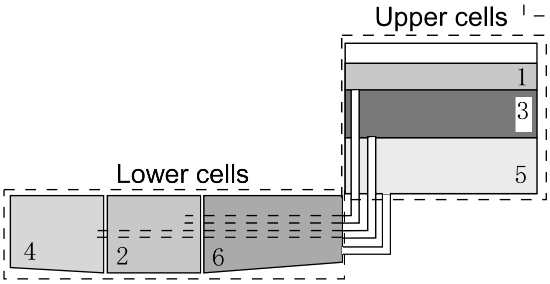
Fuel control panel
(accident aircraft)

Legend

- Transfer pump
- Ejector pump
- Boost pump
- Valve
- Check valve
- Thermistor
- Probe
- Pressure switch



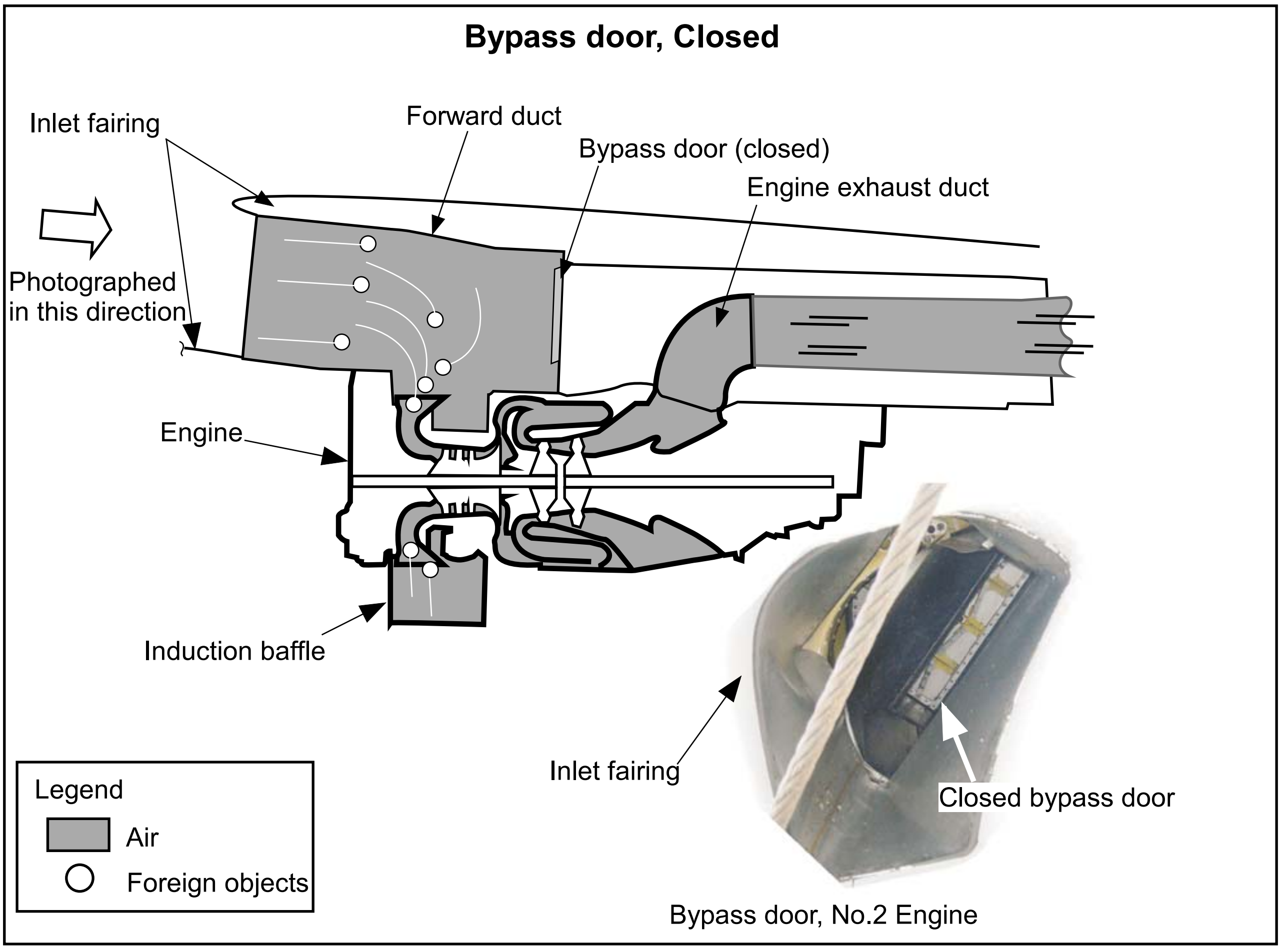
Fuel system schematic

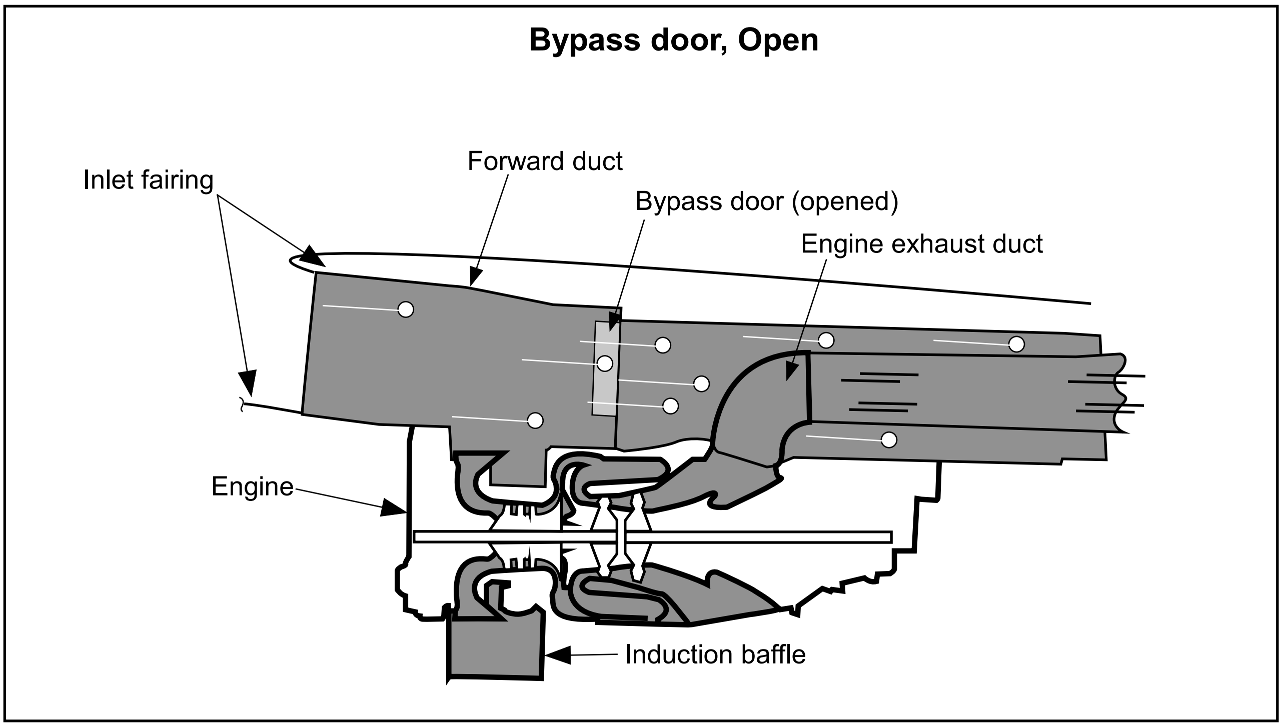


Sequence of fuel burn
(Side view of fuel cells)

Based on Bell 412 material

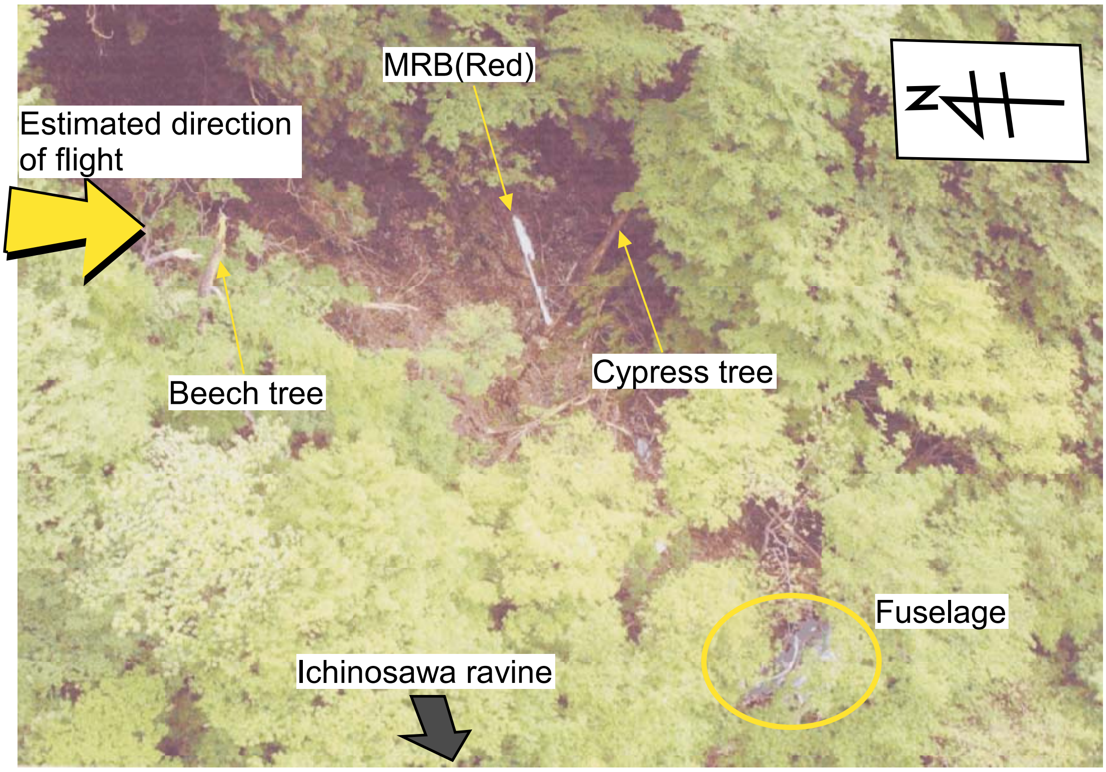
Figure 5 Particle Separator System





Based on the Bell 412 Training Manual

Picture 1 Accident Site



Note: The surface of the slope is exposed because trees were pushed down by the aircraft and the underbrush was stamped during the course of investigation activities.

Picture 2 The Aircraft

Note: This photo was taken during the course of aircraft recovery. (Aft cross tube is already detached.)