National Transportation Safety Board
Aviation Accident Final Report

Location:	Loma Alta, TX	**Accident Number:**	IAD03MA049
Date & Time:	04/26/2003, 1005 CDT	**Registration:**	N138BF
Aircraft:	Sino-Swearingen SJ30-2	**Aircraft Damage:**	Destroyed
Defining Event:		**Injuries:**	1 Fatal
Flight Conducted Under:	Part 91: General Aviation - Flight Test		

Analysis

The corporate jet was in a descent to attain a Mach 0.884 target speed during an airplane type certification flutter test. The airplane (a unique test bed) had a known speed-dependent tendency to roll right which was attributed to wing and aileron twist deviations. As the speed increased during the accident flight, the pilot had to apply full left aileron to be able to maintain airplane control. The airplane completed the test point about 30-degrees right-wing-low, and subsequently began to roll to the right, "like a barrel roll...not real fast," that the pilot reported he could not stop. Although the manufacturer's engineering analysis (which did not include any high-speed wind tunnel testing) predicted positive lateral stability up to Mach 0.90, lateral control was lost during the accident flight, and the airplane rolled about 7 times during a 49-second timeframe, from about 30,500 feet until a near-vertical ground impact. A review of telemetry data revealed that, just before the rolls began, the airplane's elevator moved to the 3.5 degrees trailing-edge-up (TEU) position, and the airplane's heading deviated right. Less than 1 second later, the rudder moved from 2 degrees trailing-edge-left (TEL), to 6.5 degrees TEL, and the combination of the TEU elevator and the left rudder input coincided with a marked increase in airplane's right deviation. Elevator-up deflection and rudder-left defection were maintained, with some variation in magnitude, to nearly the end of the data. Because the known speed-dependent tendency to roll right had created significant control problems on a previous flight, the ailerons were removed, modified and replaced, and a Gurney flap was added to the right wing. After the addition of the Gurney flap, the lateral trim margin improved to about 40 percent required (where 50 percent was neutral) up to 305 KCAS. It was then determined that flutter testing could continue to higher airspeeds if the pilot needed to apply a "small" wheel force to augment the trim. The pilot had been instructed to reduce airspeed if there was a problem during the flutter testing, and had done so during an uncommanded roll to the left on the previous flight. Telemetry data from the accident flight revealed that at initiation of the upset, the pilot attempted to level the wings and raise the nose, but the airplane continued to diverge from stable flight, and it continued to accelerate beyond the airplane's demonstrated flight diving speed. It is undetermined if the pilot could have reduced the speed of the airplane in time, during the initiation of the upset, so that the airplane would not diverge. After the accident, the company conducted high-speed wind tunnel tests, and found that lateral stability decreased with increasing Mach and angle of attack (AOA).

Lateral stability became negative (unstable) above Mach 0.83, and rudder input intended to augment lateral trim above a certain Mach could aggravate the situation. In addition, a TEU elevator input would increase AOA, and also result in deteriorated lateral stability. High speed wind tunnel data also revealed that roll authority deteriorated above Mach 0.86, and by Mach 0.88, the aileron upper and lower surfaces were both in separated flow regions. The follow-on flutter test airplane, which successfully completed the certification requirements, was equipped with vortex generators and thicker trailing-edge ailerons. It also did not require the external trim device needed on the accident airplane due to improvements in manufacturing.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:
The manufacturer's incomplete high-Mach design research, which resulted in the airplane becoming unstable and diverging into a lateral upset.

Findings

Occurrence #1: LOSS OF CONTROL - IN FLIGHT
Phase of Operation: DESCENT

Findings
1. AIRCRAFT CONTROL - NOT POSSIBLE
2. INFORMATION INSUFFICIENT - MANUFACTURER
3. (C) INADEQ SUBSTANTIATION PROCESS,INADEQ DOCUMENTATION - MANUFACTURER

Occurrence #2: IN FLIGHT COLLISION WITH TERRAIN/WATER
Phase of Operation: DESCENT - UNCONTROLLED

Findings
4. TERRAIN CONDITION - GROUND

Factual Information

HISTORY OF FLIGHT

On April 26, 2003, at 1005 central daylight time, a Sino-Swearingen Aircraft Corporation (SSAC) SJ30-2, N138BF, serial number 002, was destroyed when it impacted terrain near Loma Alta, Texas. The certificated airline transport pilot was fatally injured. Visual meteorological conditions prevailed for the flight, which departed on an instrument flight rules flight plan from San Antonio International Airport (SAT), San Antonio, Texas, at 0911. The local test flight was conducted under 14 CFR Part 91.

At the time of the accident, the airplane was undergoing flutter testing for Federal Aviation Administration (FAA) type certification. SSAC Report 30-2222, "Flight Flutter Certification Test Plan for SSAC SJ30-2," delineated the flutter testing requirements, which included the Federal Air Regulation (FAR) Part 23.629 requirement that the airplane be demonstrated to be free from flutter, control reversal, and divergence up to the "demonstrated flight diving speed" (Vdf/Mdf). The testing was to be conducted in two phases, with the first phase planned to clear the airplane to its "maximum operating limit speed" (Vmo/Mmo) of 320 KCAS/Mach 0.83, and the second phase, to clear it to its Vdf/Mdf of 372 KCAS/Mach 0.90.

Phase 1 flutter testing had been successfully completed. The first flutter mission of phase 2, flight test number 230, was flown one day before the accident flight, with the same pilot onboard. The objective of that flight was to complete flutter test points 1-12 (Mach 0.844) and 1-13 (Mach 0.864). Test point 1-12 was completed, and subsequently, the airplane went into a uncommanded roll to the left, which the pilot recovered from. Afterwards, during test point 1-13, a discrepancy was noted between the pilot's displayed airspeeds and those reported by a chase plane pilot, so the pilot terminated the flight.

After the flight, the pilot realized that he had incorrectly set up the airspeed display in the test airplane, and was flying faster than his airspeed indicated. In addition, the pilot reported, that during the flight, he had felt a "rumble" in conjunction with the left roll. In his notes, he had written, ".855", and immediately below that, "Abrupt LH Roll [space] Rumble", and beneath that, "Rudder Input?"

According to the project's flutter consultant, a Designated Engineering Representative (DER), a possible explanation for the rumble was Mach buffet. However, to help confirm there wasn't an in-flight mechanical problem with the airplane, flight test personnel assigned a second SSAC pilot as a backseat chase plane observer for the next (accident) flight, flight test number 231.

The chase plane was a contracted Northrop T-38 jet, N638TC, with a pilot and the second SSAC test pilot onboard. The accident flight was also being monitored in a telemetry van in Rock Springs, Texas, by the flutter consultant and three SSAC personnel.

Prior to the test flight, a mission briefing, led by the accident test pilot, was conducted via conference call between the San Antonio-based personnel and the telemetry van personnel. According to a briefing participant, all of the flight test cards were covered, "including the test limitations, test set-up, test points, weight and balance, airspace operational considerations, aircraft limitations, maintenance actions since last flight, instrumentation status, and chase aircraft procedures." A number of witnesses also noted that the test points briefed were 1-14 (Mach 0.884), and 1-15 (Mach 0.894) if conditions permitted.

An "SSAC Flight Briefing Guide" was also utilized, which included a review of hazard analyses, and abnormal/emergency procedures. During the briefing, the test pilot stated that he was responsible for safety of flight.

The flutter consultant also stated that he had, during previous discussions, advised that for the purpose of flutter testing, if the pilot ran out of aileron/elevator trim, the tests could still be completed, even if the pilot had to hold aileron/elevator force to steady the airplane. He further stated, however, that the continuance of the testing would never override the pilot's decision as to whether the control forces were unacceptable or hazardous.

According to the flutter consultant, after takeoff, the accident airplane climbed to 39,000 feet, and prepared for a shallow dive along an easterly track for flight test point 1-14. A telemetry lock was then obtained. However, when the airplane reached indicated Mach 0.875, the test pilot called "Mark" on the radio. [An optional test point "14A" (Mach 0.874) was listed on the flutter test card; however, on the previous day's flight, it had been crossed out.] After the "Mark" was received, the pilot initiated a single pulse input to the elevator. After checking the telemetry strips, the consultant then gave a "Go" for a single pulse to the aileron, followed by another "Go" for a single pulse to the rudder. Telemetry van personnel noted that all the modes excited were "well damped."

Telemetry van personnel also reported that after the pulses were completed, the test pilot stated that the uncommanded roll to the left (which was experienced on the previous flight), did not occur. There was also no mention of a rumble. In addition, the chase plane pilots confirmed that there were no mechanical anomalies evident on the accident airplane.

The flutter consultant further stated that the accident airplane subsequently turned back to the west and began to climb back to 39,000 feet to prepare for the [easterly] dive to the 1-14 point. Discussion between the pilot and telemetry van personnel included the fact that the 1-14 point might be the last one of the mission due to fuel concerns, particularly for the chase plane.

Following telemetry lock, the airplane began a shallow dive. At indicated Mach 0.884, the pilot called "Mark." Each control surface was again pulsed by the pilot, and the responses were again "well damped."

Following the final pulse, the pilot was cleared to the next test point, 1-15 (indicated Mach 0.894), "if flight conditions permitted the test pilot to do so." However, the pilot did not acknowledge the clearance, but instead, reported that the airplane was rolling to the right, and he couldn't stop it.

In a written statement, the chase plane pilot confirmed that after the 1-14 test point had been completed, the test pilot was cleared to accelerate to the 1-15 test point, if able. At that time, the accident airplane appeared to be in a shallow right bank with the chase plane less than 500 feet above and 500 feet behind it. According to the chase plane pilot, "very soon thereafter," about 30,000 feet, the accident airplane began rolling to the right. The rolling maneuver appeared to be stable, and continued unchanged until ground impact. The accident airplane appeared to remain intact throughout the event, and no parts were seen departing the airframe. After the accident airplane began to roll, and the test pilot stated that he couldn't stop it, the chase pilot called, "get out" twice. The accident pilot responded that he couldn't get out, that there were too many "g's."

The second SSAC test pilot, who had been in the back of the chase plane, also reported that the accident sequence began after the completion of the 1-14 test point. During the sequence, the chase plane was not close enough to observe the accident airplane's control positions; however, the second SSAC test pilot observed the accident airplane's nose to be "a little low," and in an approximately 30-degree right bank after test point 1-14 was completed. A few seconds later, the accident airplane entered a "barrel-roll type maneuver" to the right, then continued to roll, and increased its dive angle until ground impact.

When the second SSAC test pilot saw the first roll, his first thought was, "what did he do that for?" Then he saw that the accident airplane "came around and made another barrel roll. It was not around a point like an aileron roll; and it was not real fast; it looked lazy." The chase pilot then mentioned the roll to the accident pilot, who replied that he couldn't stop it. The accident pilot did not say anything further about how the airplane was performing, or what he was experiencing.

At some point during the sequence of events, the accident pilot transmitted information about the flight controls and/or aileron trim; however, witness accounts differed on what and when it was transmitted. According to the chase plane pilot, the accident pilot stated, "I can't let go" after he was cleared to test point 1-15. The flutter DER stated that the accident pilot advised he "could not release the wheel" shortly after the 1-14 aileron pulse, and a telemetry engineer, who was calling out airspeeds to the DER, stated that the accident pilot reported, "full aileron trim and I can't let go" when the accident airplane had accelerated to Mach .881, prior to the 1-14 pulses.

PERSONNEL INFORMATION

-- Accident Pilot --

The accident pilot held an airline transport pilot certificate, with ratings for the Boeing 707, 727, and 747, and Airbus 300. He also had combat experience in the Vought F8J Crusader, and served a total of 30 years as an active duty and reserve Naval officer.

According to the pilot's resume, dated July 2, 1996, he had 12-13 years of flight test experience prior to joining SSAC, including experience at LTV (Ling-Temco-Vought) Aerospace, Douglas Aircraft, the U.S. Navy, and General Electric. He was not a test pilot school graduate.

Between 1966 and 1969, the pilot flew A-1 Skyraiders, then transitioned to the A-3 Skywarrior. He subsequently flew EKA-3B conversion flights from a depot level rework facility, and later, F-8 Crusader and F-4 Phantom acceptance flights.

In 1969, the pilot qualified as a Boeing 727 flight engineer for a major airline. Later that year, when he was furloughed from the airline, he qualified as an agricultural application pilot. He later became involved in a short take off and landing (STOL) conversion as both a "project pilot" and a flight demonstration pilot, and he also flew the F-8 Crusader in an operational reserve fighter squadron.

From 1970 to 1972, the pilot was carrier-based, flying combat missions in Vietnam. He applied for the U.S. Navy Test Pilot School, but was shot down and captured about 1 week before selections were made. Once repatriated, the pilot pursued a college degree while concurrently serving as a fighter pilot instructor. The pilot subsequently completed two more tours of operational duty.

In 1973, the pilot again qualified as a flight engineer on a Boeing 727, and flew with a major airline through 1974. Between 1978 and 1983, the pilot participated in flight testing a turbine-powered agricultural application airplane, involving liquid and dry material dispersing. Between 1983 and 1985, the pilot served as a System Safety Engineer at Douglas Aircraft Company for the development of a Navy T-45 training system. As such, he was involved in hazard analysis and system safety for three prototype airplanes, along with simulators and academics. He also participated in system safety and hazard analysis for the NASA propfan program.

Between 1985 and 1988, the pilot was a flying flight test engineer on the McDonnell Douglas MD-80 transport airplane.

Records indicate that, in 1989, the pilot was hired as an "experimental test pilot" at General Electric's Flight Test Operation - Mojave. As one of only two pilots, he was "involved in virtually all aspects of testing for the various CFM Series, CF-6 Series and GE-90 Series engines." Testing included "stabilization on a test point, low altitude Vmax speed points, wind-up turns, airstart envelope determination, V2 climb profiles, over-rotation tests, aircraft stall maneuvering, high AOA investigation, zero 'g', various operability trials and profiles, plus others throughout the test envelope." The pilot became rated in the Boeing 707, 747 and Airbus 300 at that time.

The pilot also reported that he was a member of the Society of Experimental Test Pilots, and wrote the organization's Flight Readiness Review and Preflight documentation.

According to SSAC records, the pilot joined the company in 1997, and was serving as chief test pilot when the accident occurred. Prior to the accident flight, he had accumulated 294 flight hours in the accident airplane, and 331 flight hours in airplane serial number 001.

The pilot's logbook was not recovered after the accident, and according to an SSAC representative, the pilot always took his logbook with him on his flights. On July 3, 2002, the pilot's latest Federal Aviation Administration second class medical certificate was issued, and at that time, he reported 12,000 hours of total flight experience.

The second SSAC pilot reported that the accident pilot did not have experience performing flutter tests, but as chief pilot, he wanted to do it. The second pilot, who did have experience with flutter testing, provided training to the accident pilot. "I checked him out - he wanted to do it - we went out and I demo'd it, and he did it. He understood it; he's an F-8 guy. If I had any qualms about it, he wouldn't have been able to do it." The second SSAC pilot also stated that the accident pilot knew to slow the airplane should he run into any difficulty. "We discussed it a lot (power idle). We talked and talked about throttles idle. In my mind, I know he did that."

-- Second SSAC Test Pilot --

According to the second SSAC test pilot's undated resume, he had previously served as a test pilot at McDonnell Douglas on the MD-80 series and MD-11 certification programs. He also served as chief pilot, and was responsible for six test pilots and six loadmasters.

The second test pilot reported 7,000 hours of flight time, with 3,000 hours of test pilot experience over a 15-year period. He was also a graduate of the U.S. Air Force Test Pilot School.

-- DER --

Per a technical services agreement, the flutter consultant DER was hired to "provide oversight and guidance in the execution and documentation of flutter analysis" for certification compliance with FAR 23. In conjunction with the agreement, the consultant was "given authority as director of test preparation, test conduct, and analysis of results."

According to the DER's undated resume, he had worked in the field of aircraft flutter and dynamics for over 30 years. He had also been employed by Boeing for 12 years as a specialist engineer in flutter and vibration, and was involved with the Boeing 707, 727, 737, 747, and served lead engineer for the YC-14 flutter group. Previously, he performed flutter work, as a dynamics engineer, for development of the British Aircraft Corporation (BAC) Concorde. He became an independent DER in 1981, and "supported engineering work on projects ranging from the Cessna 180 to the Boeing 747 aircraft, with engineering analysis, design and testing as required for individual programs."

The DER also had several published papers to his credit, including "Transient Excitation and Data Processing Techniques Employing the Fast Fourier Transform for Aeroelastic Testing," "Effect of Stabilizer Dihedral and Static Lift on T-Tail Flutter," and "The Use of Transient Testing Techniques in the Boeing YC-14 Flutter Clearance Program."

COMPANY INFORMATION

According to a company representative, in May 1995, The Sino Swearingen Aircraft Company was formed as an international joint venture between Swearingen Aircraft, Incorporated, and Sino Aerospace Investment Corporation, Taipei, Taiwan. The Company's status later changed to a Corporation.

The original proof-of-concept SJ30, serial number 001, was built by Swearingen Aircraft, Inc., in the early 1990s, and first flew on February 13, 1991. In the mid-1990s, due to market demands and the products offered by competitors, the airplane was reconfigured. It was lengthened considerably, the wings were changed from anhedral to dihedral, and a new avionics suite was installed. It first flew in the new configuration in November 1996. By the time of the accident, the company had manufactured three more (flying) airplanes in that configuration, along with a static test platform and a fatigue test platform.

The company's headquarters were located at San Antonio International Airport, and a manufacturing facility was located in Martinsburg, West Virginia. The Martinsburg facility manufactured the vertical tail and the horizontal stabilizer. At that time, another company, Gamesa Aeronautica, of Vitoria, Spain, manufactured the wings and the fuselage. The San Antonio facility mated the wings, fuselage, and tail, installed the aircraft systems including the avionics, and flight tested the airplanes. All design and certification activities were accomplished at San Antonio.

SSAC was organized with Engineering, Manufacturing, and Quality Assurance departments reporting to the Senior Vice President of Operations. Engineering was comprised of Aerodynamics, Design, and Flight Test units. Manpower between the San Antonio and Martinsburg facilities totaled 382, of whom 118 reported to the Vice President of Engineering.

Airplane certification was being accomplished under an agreement between SSAC and the

FAA, entitled, "Project Specific Certification Plan (PSCP) for SJ30-2, Report Number 30-041." The PSCP called for the certification of a "seven-passenger (including crew) airplane of conventional metal construction powered by two aft fuselage mounted Williams [International] FJ44-2A medium bypass turbofan engines." The airplane was to be certified in the commuter category for single pilot operation and all-weather capability, with a maximum operating Mach of 0.83 and a maximum altitude of 49,000 feet.

Formal engineering procedures governed airplane acceptance and development.

Engineering acceptance of flight test airplanes prior to first flight was governed by SSAC Engineering Procedure 007 (EP007), "a formal process...to determine and document the airworthiness of an aircraft prior to acceptance by the SSAC Test Operations Department." The procedure included a review by the SSAC Flight Safety Review Board, and a Flight Safety Review Checklist, including a flight test risk assessment.

Engineering changes to flight test airplanes was governed by SSAC Engineering Procedure 006 (EP006), which delineated "the method of configuration control to be used for the 'experimental' licensed aircraft which are owned and/or operated by...SSAC."

ACCIDENT AIRPLANE INFORMATION

The accident airplane, serial number 002, was first flown on November 11, 2000. At the time of the accident, the airplane was operating under a Special Airworthiness Certificate with Experimental Operating Limitations for the Purpose of Research and Development.

The airplane was inspected using an Approved Aircraft Inspection Program (AAIP) titled, "SJ30-2 Inspection Procedures Aircraft S/N 002, Report Number: QA-INSP-500 (QA-500)." Data accumulated during the airplane's design and operational testing was analyzed to formulate the inspection program requirements.

Inspections included the First Flight of Day Inspection, Next Flight Inspection, After Last Flight Inspection, Periodic/Phase Inspections (A, B, C) and Special Inspections. The Periodic/Phase inspections were accomplished at 100-hour intervals. Inspections were recorded on the Flight Test Work Order (FTWO).

Aircraft maintenance manuals had not been developed for the airplane. Maintenance was accomplished by FAA-certificated technicians using aircraft drawings and specifications in conjunction with vendor component maintenance manuals. Maintenance work was also recorded on the FTWO.

The last Periodic/Phase Inspection was a "B" Check, accomplished on January 14, 2003, at 284.2 hours. A First Flight of Day Inspection was accomplished on April 26, 2003, for the accident flight, at 315.9 hours.

According to an FAA inspector, a review of aircraft maintenance records revealed that SSAC was in compliance with the requirements of the approved aircraft inspection program.

The airplane was equipped with a trailing cone for static air pressure and a nose boom for dynamic air pressure. The combined inputs resulted in a "reference system airspeed." The pilot would have had to operate two cockpit switches to be able to display reference system airspeed. Failure to do so would have resulted in him reading a lower airspeed, generated from the airplane's internal airspeed indicating system.

The airplane was also instrumented to communicate 27 critical test parameters at 300 samples per second to a ground station van via telemetry, in order to support the flutter test plan. In addition, the airplane also had onboard computers, which recorded over 450 flight parameters.

METEROLOGICAL INFORMATION

Weather, recorded at an airport about 35 nautical miles to the south, included clear skies, winds from 330 degrees true at 10 knots, and 10 miles visibility.

WRECKAGE AND IMPACT INFORMATION

The wreckage was located at 29 degrees, 52.37 minutes north latitude, 100 degrees, 57.65 minutes west longitude, about 250 degrees magnetic, 10 nautical miles southwest of Loma Alta, Texas, and 350 degrees magnetic, 30 nautical miles north of Del Rio, Texas.

The accident site was located in a remote area of sparsely vegetated plateaus and canyons, at an elevation of 1,741 feet, near the top of one of the plateaus. The main crater was cut almost straight down, about 5 feet, into a sandstone formation. There were additional cuts, consistent with wing positions, oriented along a 085/265-degrees magnetic axis.

The wreckage was fragmented, with debris spread over an area of approximately 9 acres, dispersed 360 degrees around the impact crater. Evidence of all flight control surfaces was found at the scene. Slat tracks were identified; however, no slat structures were identified in the debris field. There was no evidence of an in-flight fire or in-flight failure of structural elements, and all fracture surfaces examined exhibited evidence of static overload. Control continuity could not be confirmed due to the severity of the impact damage.

The airplane's onboard computer hard drives were located; however, their condition precluded any data recovery.

MEDICAL AND PATHOLOGICAL INFORMATION

An autopsy and toxicological testing could not be performed.

TESTS AND RESEARCH

A Vehicle Performance Group was formed to review flight test and other pertinent data, including radar, telemetry parameters, lateral control and lateral trim documentation, and transonic wind tunnel tests. Results excerpted from the Vehicle Performance Group Study include:

-- Radar --

Long and short range radar data indicated that the accident airplane was on an easterly course, about 35 miles north of Del Rio, Texas at an altitude of 30,500 feet when the accident event began. The accident airplane was transmitting beacon code 4761 during the flight test and the chase plane, as second in a flight of two, was not transmitting an independent transponder code.

Subsequent to the accident, the chase plane began transmitting beacon code 4761.

-- Telemetry Data --

The telemetry data for the last 3 minutes of flight 231 was transcribed from binary to engineering units by SSAC personnel, and provided to the Safety Board.

The telemetry data included airplane flight conditions (altitude, airspeed, Mach number);

magnetic heading; control surface positions for the elevator, rudder, and ventral rudder; fuel weight; and 19 accelerometer parameters requested to support the flutter certification testing. Onboard parameters of interest that were recorded, but unrecoverable, included accelerations near the airplane's center of gravity; angle of attack and sideslip angle; roll and pitch attitude; aileron surface, speedbrake, slat, flap, and gear positions; engine parameters; control input positions; and column, wheel, and pedal forces.

No significant telemetry data dropouts occurred prior to the initiation of the event. However, the recorded telemetry data subsequent to the lateral upset event contained a large number of dropouts, which were attributed to the masking of the onboard antenna as the airplane rolled.

Telemetry scale limits were met or exceeded for three parameters. The calibrated airspeed reached, and remained at its maximum threshold value (400 knots) by 268 seconds, about 27 seconds prior to the end of data. In addition, the indicated Mach number maximum threshold value (Mach 1.0) was maintained between 272.9 and 278.3 seconds, and the telemetry minimum pressure altitude (10,000 feet) was reached, and maintained, beginning about 4 seconds prior to the end of the data.

-- Accident Event Timeline --

The timeline was based in part on SSAC document, "S/N 002 Accident Investigation Final Report: Lateral Instability Theory," dated August 1, 2003.

The telemetry data began at 130 seconds (10:02:10) with the airplane about 38,000 feet, Mach 0.805 passing through a magnetic heading of 36 degrees as it executed a right, shallow, descending turn toward a magnetic heading of approximately 073 degrees. The airplane accelerated to about Mach 0.83 by the time it completed the turn, and continued its shallow descent, accelerating to about Mach 0.85 by 180 seconds. The airplane stabilized about Mach 0.85 for nearly 8 seconds, while passing through 36,000 feet, then passed Mach 0.86 about 193 seconds. One second later, accelerometers recorded noticeably higher amplitude oscillations, consistent with high-speed buffet. (The lift coefficient at 194 seconds was calculated to be 0.25, which correlated to what would have been expected, based on the SJ30-2 buffet boundary curve.)

The airplane reached Mach 0.87 about 202 seconds, and maintained that airspeed as it passed through 33,500 feet. The airplane then reached Mach 0.88 at approximately 214 seconds, and as it stabilized at that airspeed, the rudder position transitioned from about 0 degrees, to about 1.5- to 2-degrees trailing-edge-left (TEL).

An elevator pulse was completed at 218.5 seconds, while the airplane was passing through 33,000 feet on a heading of 074 degrees magnetic.

A rudder pulse was completed at 228.5 seconds, while the airplane was passing through 31,500 feet.

An aileron pulse was completed by about 239 seconds, as the airplane passed through 30,500 feet.

Before the aileron pulse damped out, the rudder position moved, from about 2 degrees TEL to about 3.5 degrees TEL, during a 2-second timeframe. The ventral rudder position moved about 0.75 degrees TEL, the same direction as the rudder, between 237.8 and 243.2 seconds. About 240 seconds, and over a 3.2-second period, airplane heading deviated nose-right from about 074 to 076.5 degrees magnetic. About that time, the chase plane pilots reported that the accident airplane was in a shallow- to 30-degrees right bank.

At 243.2 seconds, the rudder moved about 1 degree TEL, from 3.5 to 4.5 degrees TEL, and the airplane-nose-right heading rate was briefly arrested at 244.4 seconds.

Until 243.2 seconds, the elevator remained relatively constant at its initial test condition position, near 1-degree trailing-edge-down (TED). After time 243.2, the ventral rudder position appeared to represent a scaled, offset reflection of the rudder position time history.

At 244.6 seconds, the elevator moved to about 3.5 degrees TEU in 1.8 seconds. The elevator maintained positions between 2 and 5 degrees TEU for the next 34 seconds. Also, about 244.6 seconds, as the elevator moved TEU, the airplane heading once again deviated airplane-nose-right.

At 245 seconds, rudder rate increased significantly, as the rudder moved 2 degrees TEL, over a 1-second period, to 6.5 degrees TEL.

The combination of increased TEU elevator and increased and rudder TEL coincided with a marked increase in airplane nose right heading rate. From about 246.2 seconds to the end of the telemetry data, magnetic heading established a periodic oscillation between 065 and 095 degrees magnetic with periods that varied between 6 and 9 seconds per cycle.

At 254 seconds, the accident airplane completed one roll, and through the end of telemetry, at 295.1 seconds, it completed about six more rolls. Elevator TEU deflection and rudder TEL deflection were maintained, with some variation in magnitude, to nearly the end of the data. Calibrated airspeed and Mach number increased to well beyond the SJ30-2 Vmo/Mmo and Vdf/Mdf design goals during the accident descent.

-- Performance Calculations --

Flight 231 pressure altitude, Mach number, and rudder position telemetry data were used to calculate the airspeed, ground speed, flight path angle, and sideslip angle. Radiosonde data was used to calculate the speed of sound. As the accident airplane accelerated toward the test condition Mach number, it transitioned from level flight to a flight path angle about 7 degrees below the horizon. The flight path angle was about 10 degrees below the horizon at the completion of the aileron pulse. At 243.2 seconds, as rudder deflection TEL opposed the airplane nose-right-heading deviation, the airplane's descent became increasingly steep. The flight path angle continued to decrease toward a final estimated value of 77 degrees below the horizon.

Sideslip angle was estimated as a function of rudder position based on SJ30-2 steady heading sideslip data. Results were considered valid only for periods when 1) the airplane was maintaining a relatively steady heading, and 2) rudder position was constant or slowly transitioning. Sideslip angle results were plotted between 210 and 247.5 seconds. Sideslip angle was calculated to vary between, at most, plus/minus 1 degree until the aileron pulse, when it increased to about 2 degrees between 238 and 243.2 seconds. The sideslip angle increased toward 2.7 degrees with increasing rudder TEL deflection between 243.2 and 244.4 seconds, at which point, the airplane established a nearly constant roll rate during the high speed descent.

-- Other Telemetry Data Features --

The forward fuselage lateral and vertical acceleration parameters contained distinct features or "spikes" 10 times during the data collection. The features appeared only in the two forward fuselage accelerometer channels, which SSAC personnel attributed to interference from pilot radio transmissions.

The character of the left and right aileron accelerometer data changed between 220 and 230 seconds. The left hand (LH) aileron data indicated a cycle (plus 6 g's at 222.5 seconds; minus 3 g's at 228 seconds) not present in the right hand (RH) aileron data. The LH aileron cycle occurred at approximately 0.1 Hz. SSAC personnel concluded that the frequency was too low for a piezo-electric accelerometer measurement to be valid, and that the LH aileron accelerometer data feature did not likely reflect an actual flight event.

-- Accident Airplane Lateral Control History --

The lateral trim system used an adjustable trim spring to apply a constant force to the control wheel. The spring rate of the installed lateral trim system was equivalent to about 10 pounds of pilot wheel force, or about 15 percent total roll authority. The constant force design dictated that the amount of trim required to balance an aerodynamic force asymmetry was speed-dependent.

Utilizing telemetry and witness information, the Airplane Performance Group documented the airplane's lateral control history, which included:

In 1997, SSAC purchased a drag chute and developed flight test installation plans. At some point between 1997 and 2002, a decision was made not to implement the high speed drag chute installation, originally planned for flutter testing, due to pilot concerns about the possibility of an inadvertent chute deployment.

On May 7, 2002, a Temporary Test Aircraft Limitation (TTAL) was issued that limited pilot use of aileron trim to the 20- to 80-percent range of a 0- to 100-percent scale, where 50 percent was neutral. The TTAL was issued because the aileron trim motor bogged down at approximately 13.8 percent and 92 percent of travel.

Prior to flight 114, which occurred on June 1, 2002, a speed restriction of 250 KCAS was put in place. In addition, it was discovered that the airplane required a significant amount of roll trim adjustment, and that roll trim requirements were speed-dependent. As a result, the ailerons were removed, measured, and replaced, to attempt to correct twist deviations from the aileron surface design.

During flight 114, the airplane required much less roll trim adjustment, the roll trim requirement was consistently left-wing-down (LWD) and increased with airspeed, and the airplane could be trimmed in the lateral direction within the 250 KCAS speed restriction. SSAC personnel subsequently concluded that the airplane's tendency to roll right-wing-down (RWD) could be attributed to wing, and remaining aileron twist deviations from their respective surface designs.

After October 2002, the airspeed restriction was increased to 320 KCAS/Mach 0.83 following completion of Phase 1 flutter testing. The consistent LWD roll trim requirement was a known airplane-specific characteristic, which required nearly full LWD lateral trim at 320 KCAS.

For flight tests 199 and 200, December 16-17, 2002, the airplane was instrumented with tufts on the left and right wing upper surfaces. Two video cameras (one camera per wing) were installed to record real time tuft positions on each wing upper surface. Tuft testing confirmed the presence of large regions of shock-induced separation above Mach 0.81.

On April 14, 2003, the airplane's speedbrake travel was limited to 17.5 degrees of a nominal 35-degrees design travel, to reduce undesirable speedbrake deployment pitch characteristics (i.e., speedbrake deployment could cause a large, airplane-nose-down pitching moment).

On April 15, 2003, during an SSAC Safety Review Board (SRB) meeting, it was determined that due to the airplane's lateral trim issue and flutter test plan airspeeds exceeding 320 KCAS, full LWD trim and pilot hand pressure on the yoke would be required. The use of a Gurney flap on the right wing tip was approved. (The Gurney flap was an aerodynamic device intended to balance the airplane in the lateral axis, independent of airspeed, and restore lateral trim margin.)

On April 24, 2003, flight 229 was conducted to quantify Gurney flap effectiveness, flight-test the flutter instrumentation, and perform a telemetry range check. The Gurney flap improved the lateral trim margin, and for airspeeds up to 305 KCAS, approximately 40 percent lateral trim was required on a scale from 0 to 100 percent, where 50 percent was neutral.

Subsequent to the flight, SSAC personnel considered the fact that the airplane would likely require additional LWD control input to trim laterally as airspeed increased beyond Vmo (320 KCAS). The flutter test consultant indicated that the flutter data analysis would be valid if roll control pulses were superimposed on a basic wheel force required to hold wings level.

On April 25, 2003, as part of the pre-flight test review for flight 230, SSAC personnel decided to continue with the flutter testing if the pilot needed to apply a "small" wheel force to trim laterally as airspeed increased beyond Vmo (320 KCAS).

During flight 230, flutter test point 1-12 was completed. All available aileron trim was required at Mach 0.84 for the point, at altitudes between 31,000 and 30,000 feet. Rudder pedal was used to augment aileron trim (set at approximately 25 percent) as the airplane descended from 33,000 to 31,000 feet.

Data revealed that all of the earlier TTAL lateral trim margin (20 to 80 percent) was required to trim the airplane between Mach 0.84 and 0.86.

During flight 230, [approaching] test point 1-13, the airplane experienced an uncommanded LWD roll. The roll event was corrected by pilot wheel input over a period of about 20 seconds as the airplane decelerated below Mach 0.85. Rudder pedal was also used to augment the aileron roll control during the recovery.

Subsequent to the flight, SSAC personnel concluded that the LWD roll resembled a wing drop, likely caused by the presence of shock-induced separation. The pilot was briefed to expect increased vibration, buffeting, and possible wing drops as the airplane passed the 1g buffet boundary at Mach 0.86.

-- Stability and Control Characteristics --

Prior to the accident, SSAC estimated the SJ30-2 high speed stability and control characteristics by extrapolating low speed wind tunnel data, using methods in the USAF Stability and Control Data Compendium (DATCOM), conducting numerical simulation with Computational Fluid Dynamics (CFD) tools, and extrapolating flight test data.

-- Wind Tunnel Testing --

Between 1996 and 2002, SSAC personnel conducted eight low speed wind tunnel tests. A baseline SJ30-2 configuration was developed as a result of three tests completed between February 1996 and February 1997. Aerodynamic stability and control data for the production SJ30-2 configuration was collected during tests in October 1997, and May 1998. Secondary flight control surface asymmetry deployment effects were evaluated in September 2001. Speedbrake pitching moment characteristics, stall chute stinger/emergency egress deflector effects, and alternative speedbrake configurations were analyzed in August and October 2002. The low speed wind tunnel data revealed that separation, due to either speedbrake deployment or high (post-stall) angles of attack, tended to reduce wing lateral stability.

Following the flight 231 accident, SSAC personnel developed a test plan and authorized a transonic test to define the high speed stability and control characteristics of the SJ30-2. A1/9th scale model was built to SJ30-2 design loft specifications and completed in December 2003. The model design enabled hinge moment measurements generated by specific hinge-wise deflections of the horizontal stabilizer, aileron, elevator, rudder, and outboard spoiler/speedbrake flight control surfaces. In addition, vortex generator, thick trailing edge flap and aileron, Gurney flap, winglet, strake, and wing blade components were built and tested. During January 2004, transonic testing took place in an 8- by 9-foot transonic tunnel in Bedford, England.

In May 2004, results of the transonic test were presented to the Airplane Performance Group. The test data indicated that lateral stability on the SJ30-2 deteriorated with increasing Mach number and angle of attack. Lateral stability, measured in terms of rolling moment due to sideslip, became negative (unstable) above Mach 0.83. Because of this, a rudder input intended to augment the lateral trim (or roll capability) and raise a low wing could instead, beyond a certain Mach number, actually aggravate the situation. Similarly, an elevator TEU input would tend to increase the angle of attack, also resulting in deteriorated lateral stability.

The transonic wind tunnel test data also provided evidence that roll authority deteriorated above Mach 0.86. Flow visualization results revealed that upper wing surface flow separated between Mach 0.84 and 0.88, and lower wing surface flow separated between Mach 0.86 and 0.88, at 2-degrees angle of attack and 0-degree sideslip angle. A 1-degree angle of attack was representative of the accident flight condition lift coefficient.

-- Computational Fluid Dynamics --

SSAC personnel utilized Computational Fluid Dynamics (CFD) methods for wing design, and to supplement SJ30-2 high speed stability and control database. Prior to the accident, vortex lattice and Euler methods were primarily used. Euler methods tended to predict shock locations farther aft than actual shock locations during transonic flight conditions.

Wing design calculations for the SA30 (a pre-SJ30-2 prototype) and SJ30-2 were performed using WIBCO, a NASA/Grumman transonic small disturbance code. A coupled integral boundary layer computation capability was available in WIBCO, but the code lacked an asymmetric analysis capability. WIBCO was used primarily by SSAC for cruise analysis, although runs were also made at Mach 0.88 (the dive Mach number at the time) to validate the onset of separation.

Prior to the accident, a three-dimensional MGAERO Euler code (inviscid mode) was used to design the pylon for cruise, analyze the flap track fairings, and provide stability predictions. MGAERO predicted a reduction in lateral stability above Mach 0.815, but positive lateral stability up to Mach 0.90. Two-dimensional CFD aileron studies indicted that aileron power would decrease with increasing Mach number.

Following the accident, SSAC made inviscid calculations up to Mach 0.9, including sideslip, in an attempt to understand three-dimensional, transonic, asymmetric characteristics. A more advanced, fully viscous NSAERO Navier-Stokes CFD code was also utilized to gain additional insight, and other advanced CFD methods were utilized to enhance the prediction of stability and control derivatives.

-- Accident Airplane Flight Testing --

Steady heading sideslip flight tests conducted with the accident airplane revealed a positive lateral stability from 1.2 Vs up to Mach 0.817. Sideslip angles up to 6 degrees were tested at Mach 0.817. Bank-to-bank roll testing demonstrated adequate aileron authority to Mach 0.819. Flight 230 data demonstrated the airplane's response to aileron and rudder inputs above Mmo.

Flight 199 and flight 200 high speed tuft test data confirmed the presence of large regions of shock-induced separation above Mach 0.81.

-- Airplane Improvements --

SSAC personnel made aerodynamic improvements to the SJ30-2 following the accident, as a result of post-accident design and development efforts. Vortex generators were added to the wings to delay the onset of shock-induced separation, and thicker trailing edge ailerons were installed to improve aileron effectiveness at high Mach numbers. In addition, a high-Mach-number roll spoiler system was prepared, to augment roll control above Mach 0.835.

As a result of additional design work initiated prior to the accident, the single speedbrake panel on each wing was relocated farther outboard to minimize the large pitch-down effects caused by tail lift interference, and the speedbrakes became operational at all airspeeds within the design deployment range.

The new SJ30-2 flight flutter test airplane, serial number 004, N404SJ, was equipped with a high speed drag chute before flutter testing resumed. (Airplane serial number 003, N30SJ, was used primarily as a systems validation platform.)

-- Post-Accident Flight Test Data (Serial Number 004) --

High speed flight test results on serial number 004, which incorporated the configuration modifications outlined above, demonstrated improved SJ30-2 high speed stability and control characteristics. The airplane flew multiple flutter test points to Vd/Md (372 KCAS/0.90 Mach). The point of neutral lateral stability was found to be approximately 0.015 Mach higher at the critical altitude (28,000 ft) than that predicted by the transonic wind tunnel data. The modified SJ30-2 configuration maintained a positive lateral stability at Mmo (0.83 Mach) and demonstrated neutral lateral stability at approximately 0.85 Mach.

High-speed dive recovery (deceleration from Mach 0.885 to Mach 0.85), accomplished by reducing thrust to idle, resulted in a return to a laterally stable flight regime within about 9 seconds. Releasing rudder input from a nominally stabilized sideslip condition caused the airplane to return to wings level flight at all Mach numbers tested up to 0.90 Mach, even when the rolling coefficient moment due to sideslip was positive. Finally, the modified configuration repeatedly demonstrated controlled flight into the "unstable" regime, with positive roll control at all times and rapid recovery to Mmo when required.

SSAC successfully completed SJ30-2 flight flutter testing in August 2004, and demonstrated that the high-Mach-number roll spoiler, which was never installed, was not needed.

ADDITIONAL INFORMATION

-- Additional Airplane Improvements --

According to an SSAC representative, follow-on airplanes, serial numbers 003 (used primarily for systems validation), and 004 (handling and performance), exhibited well-balanced fight characteristics that did not require external trim devices. Serial number 002 was the first airplane to utilize current production tooling, while 003 and 004 represented continuous improvements in build accuracy due to the "learning curve and improvements in manufacturing tolerances."

-- Company Improvements --

According to the company's senior vice president of operations, in addition to the airplane improvements previously noted, the company initiated other improvements since the accident, including:

-- Personnel --

- Hired additional test pilots and flight test engineers, all having previous business jet certification experience.

- Had all pilots and flight test engineers go through "recovery from unusual attitudes" training.

- Retained industry experts in aerodynamics, stability and flutter.

- Contracted outside experts to review all flight test reports for flight safety and duration.

- Enhanced the cross-functionality of flight test department personnel.

-- Equipment --

- Purchased a new telemetry van and equipment to provide 360-degree tracking, 1120 parameters, and a hot microphone from the test aircraft embedded in the data transmission.

- Moved the test area for critical flights to Edwards Air Force Base to utilize special test airspace and test equipment.

-- Processes --

- Re-examined company safety board review procedures to ensure that the chairman and members clearly understood their roles and authority.

- Hired additional safety board review members.

- Initiated a process to gradually step up speed and altitude tests, by comparing actual data to high speed wing tunnel data.

- Required review and approval by the company aerodynamics group prior to all flight test plans at Mach 0.83 or above.

-- Wreckage Release --

On September 17, 2004, the wreckage was released, and acknowledged by a representative of

SSAC.

Pilot Information

Certificate:	Airline Transport	**Age:**	59, Male
Airplane Rating(s):	Multi-engine Land; Single-engine Land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	Seatbelt, Shoulder harness
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	Airplane Single-engine	**Toxicology Performed:**	No
Medical Certification:	Class 2 Valid Medical--w/ waivers/lim.	**Last Medical Exam:**	07/03/2002
Occupational Pilot:		**Last Flight Review or Equivalent:**	
Flight Time:	12000 hours (Total, all aircraft), 625 hours (Total, this make and model), 39 hours (Last 90 days, all aircraft), 17 hours (Last 30 days, all aircraft), 3 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Manufacturer:	Sino-Swearingen	**Registration:**	N138BF
Model/Series:	SJ30-2	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	No
Airworthiness Certificate:	Experimental	**Serial Number:**	002
Landing Gear Type:	Tricycle	**Seats:**	3
Date/Type of Last Inspection:	01/28/2003, Continuous Airworthiness	**Certified Max Gross Wt.:**	13600 lbs
Time Since Last Inspection:	60 Hours	**Engines:**	2 Turbo Fan
Airframe Total Time:	284 Hours	**Engine Manufacturer:**	Williams International
ELT:	Installed, not activated	**Engine Model/Series:**	FJ-44-2A
Registered Owner:	Sino-Swearingen Aircraft Company	**Rated Power:**	2300 lbs
Operator:	Sino-Swearingen Aircraft Company	**Air Carrier Operating Certificate:**	None

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual Conditions	**Condition of Light:**	Day
Observation Facility, Elevation:	DRT, 1000 ft msl	**Observation Time:**	0953 CDT
Distance from Accident Site:	35 Nautical Miles	**Direction from Accident Site:**	180°
Lowest Cloud Condition:	Clear	**Temperature/Dew Point:**	16°C / 5°C
Lowest Ceiling:	None	**Visibility**	10 Miles
Wind Speed/Gusts, Direction:	10 knots, 330°	**Visibility (RVR):**	
Altimeter Setting:	30.16 inches Hg	**Visibility (RVV):**	
Precipitation and Obscuration:			
Departure Point:	San Antonio, TX (SAT)	**Type of Flight Plan Filed:**	IFR
Destination:		**Type of Clearance:**	IFR
Departure Time:	0911 CDT	**Type of Airspace:**	Class A

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:	N/A	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 Fatal	**Latitude, Longitude:**	29.872778, -100.960833

Administrative Information

Investigator In Charge (IIC):	Paul R Cox	**Adopted Date:**	03/30/2005
Additional Participating Persons:	Eric West; FAA/AAI-100; Washington, DC Robert E Homan; Sino Swearingen; San Antonio, TX J. Chris Greene; Williams International; Walled Lake, MI		
Publish Date:			
Investigation Docket:	NTSB accident and incident dockets serve as permanent archival information for the NTSB's investigations. Dockets released prior to June 1, 2009 are publicly available from the NTSB's Record Management Division at pubinq@ntsb.gov, or at 800-877-6799. Dockets released after this date are available at http://dms.ntsb.gov/pubdms/.		