

PROXIMATE CAUSE

- Pilot entered a 240-degree roll through inverted, and the nose down pitch attitude of his aircraft increased. Although a dive recovery was initiated, the aircraft impacted the ground, killing the pilot.

UNDERLYING ISSUES

- Channelized Attention and Disorientation
- Personal Equipment and Ergonomics
- Organizational Training

AFTERMATH

- United States Air Force's released Accident Investigation Board Report placed blame on pilot error.
- After civil legal action against aircraft manufacturer, Emergency Oxygen System activation mechanism components involved in the mishap have been replaced and upgraded.

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Breathe

Survival and the United States' Most Advanced Fighter Jet

November 16, 2010, Joint Base Elmendorf-Richardson (JBER), Alaska: On a clear and quiet night, six United States Air Force (USAF) F-22A Raptor fighter jets departed from base to intercept and skirmish against four USAF F-16 fighter jets for an opposed air-to-ground attack training mission. The training mission went according to plan, but during the return-to-base (RTB) phase of the flight, one F-22A crashed. The pilot did not attempt an ejection and was killed in the crash.

BACKGROUND

The F-22A Raptor

Arguably the world's most advanced modern fighter jet, the Lockheed Martin/Boeing F-22A Raptor performs both air-to-air and air-to-ground roles with unprecedented capability. The fifth-generation, single seat, twin-engine F-22A is supermaneuverable (controlled loss of control) and utilizes state-of-the-art avionics, stealth, and supersonic cruise technology. The aircraft was first introduced into the USAF in December of 2005.

The aircraft involved in the mishap, tail number 06-4125, was properly inspected and maintained and had no history of reoccurring maintenance issues.

The Mission

At 6:17 p.m. Alaska Standard Time (AKST), the F-22A, tail number 06-

4125, departed Joint Base Elmendorf-Richardson in Anchorage for a simulated air-to-ground attack training mission against opposing fighters.

The weather in the area was clear with unlimited visibility and significant moon illumination over snow covered terrain beneath military airspace. Six F-22As with callsigns Jake 01 through 03 and Rocky 01 through 03 comprised the attack force. The six Raptors would encounter four F-16 Falcons from Eielson Air Force Base, near Fairbanks, Alaska, callsigns Mig 01 through 04.

Frigid operating temperatures called for the use of Category III cold weather gear. The insulated and bulky flight suit and gloves ensure pilot survivability if ejecting over arctic terrain. Night attack flying also necessitated the use of night vision goggles (NVGs). This was the first mission of the season involving Category III equipment.



Figure 1. Two F-22A Raptors taxiing on a runway at Joint Base Elmendorf-Richardson, Alaska.

WHAT HAPPENED

At 4:35 p.m. AKST, the six F-22A pilots received a final weather briefing before departing for the mission. They were delayed approximately 20 minutes due to crosswinds; the pilots received final briefing updates after the winds fell within normal limits. The pilots used Operational Risk Management (ORM)—a systematic decision-making and risk-identification process—to evaluate the mission risk. The mission rated in the “High” range, due to night operations, and delayed takeoff for winds. Further, the mission was the mishap pilot’s second active event for the day (the first was acting as the supervisor of flying for an earlier mission). The operations supervisor made the decision to continue, based on clear weather, diminished winds, and minimal mission changes.

Ground operations were uneventful. Jake flight took off at 6:05 p.m. AKST and Rocky flights took off 10 minutes later at 6:15 p.m. The F-22As successfully refueled and completed tactical maneuvers. Rocky flight proceeded toward the airspace exit point to return to base.

At 7:39:57 p.m., data from the flight leader Rocky 01’s Intra-Flight Data Link (IFDL) showed Rocky 03 at 13 nautical miles ahead. Rocky 01 directed Rocky 03 to return to a 2-nautical-mile trail formation. Rocky 03 acknowledged; it was the mishap pilot’s last radio call. Rocky 03 initiated a climbing right hand turn to rejoin, achieving a maximum altitude of 51,720 feet mean sea level (MSL), and crossed Rocky 01’s projected flight path. Rocky 03 then descended into trail formation.

At 7:42:18 p.m., Rocky 03’s fire protection system (FPS) detected a bleed air leak in the center bleed air ducting from both engines. Bleed air is hot, compressed air drawn from within the engine and used for auxiliary purposes in the aircraft (e.g., de-icing, cabin pressurization, pneumatics). The Integrated Vehicle Subsystem Controller (IVSC) displayed caution BLEED HOT to the pilot’s heads up display while requesting the Environmental Control System (ECS) to isolate the center bleed system. The IVSC commanded the bleed air ducts closed, which stopped operational bleed airflow to ECS.

The ECS was then unable to support the on-board oxygen generating system (OBOGS). The pilot would have immediately felt suffocated and would have struggled to breathe.

Rocky 03 was at 50,870 feet MSL, 1.23 Mach, 1.5 g, with a vertical velocity indication (VVI) of -1,700 feet per minute.

Rocky 03 retarded the throttles to idle power and continued the controlled descending right hand turn to a lower altitude in accordance with procedure until 7:42:45 p.m. There had been no pressure to the pilot’s oxygen mask since 7:42:37 p.m. For the next 8 seconds, the Rocky 03 made no throttle, pedal, or stick movements, but maintained a relatively stable bank.

At 7:42:53 p.m., the pilot input a combination of right forward stick and right pedal, which initiated a 240-degree descending right roll at greater than 45 degrees per second. The pilot had rolled through inverted and was plummeting down at a rate of -57,800 feet per minute. There were no stick inputs and only very minor pedal inputs for the next 15 seconds. As the jet descended rapidly past 19,000 feet MSL, a CABIN PRESSURE caution warned that cabin pressure had risen above normal. Upon passing 12,400 feet MSL, an AIR COOLING caution activated—a normal occurrence 60 seconds after a C BLEED HOT caution if the avionics were not receiving adequate cooling air.

At 7:43:24 p.m., the pilot attempted a dive recovery at 5,470 feet MSL by pulling aft on the stick, producing a 7.4-g pull up maneuver, but was too late. The aircraft impacted the ground 3 seconds later at a rate of -57,900 feet per minute, inflicting fatal injuries to the pilot and destroying the aircraft.

The impact site is approximately 120 nautical miles north of base in the Talkeetna Mountain range. The debris field consisted of small aircraft and engine pieces extending approximately .25 miles from the crater.

PROXIMATE CAUSE

Attempting to rejoin with his flight lead during the return-to-base portion of a training mission, the mishap pilot entered a 240 degree roll through inverted, and the nose down pitch attitude of his aircraft increased. Although a dive recovery was initiated, the aircraft impacted the ground, killing the mishap pilot.

UNDERLYING ISSUES

The USAF Aircraft Accident Investigation Board Report for the incident ruled that maintenance issues with the aircraft did not contribute to the mishap and that all maintenance actions were in order and appropriate. The board also ruled out other aircraft hardware and software, weather, pilot qualification, rest, operations, and supervision. Human factors were identified as causal to the mishap.

Channelized Attention and Disorientation

The Department of Defense Human Factors Analysis and Classification System defines channelized attention



Figure 2. Rocky 03 during bank to return to trail formation.

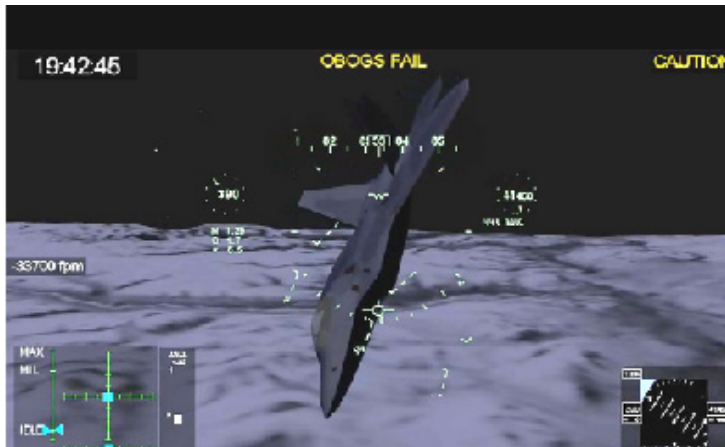


Figure 3. Rocky 03 descending to lower altitude.

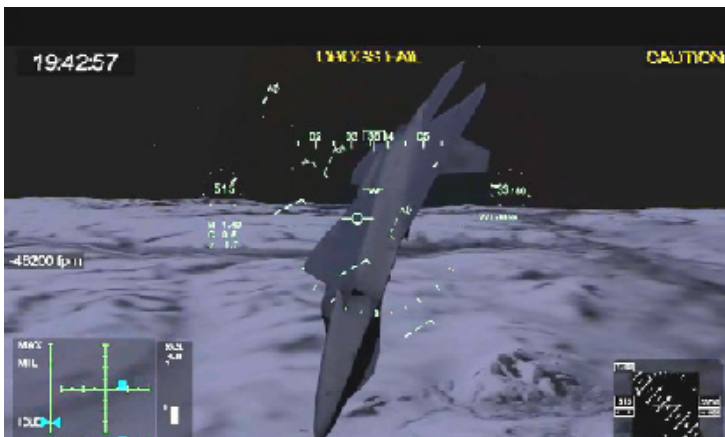


Figure 4. Rocky 03 rolling 240 degrees to inverted.

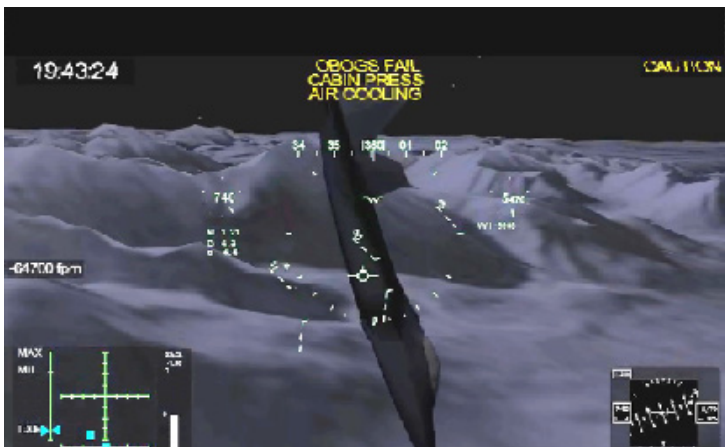


Figure 5. Rocky 03 attempting a dive recovery maneuver.

as “focusing all conscious attention on a limited number of environmental cues to the exclusion of others of a subjectively equal or higher or more immediate priority, leading to an unsafe situation.”

According to the F-22A OBOGS failure checklist, the mishap pilot was to activate the emergency oxygen system (EOS), if he was experiencing hypoxia or other physiological symptoms such as restricted breathing. However, the EOS was never activated. The investigation board deemed it likely that when the airflow to the pilot’s mask stopped, the pilot’s attention channelized on restoring the airflow by activating the EOS. While the board ruled out sudden incapacitation or unconsciousness as contributory, its only stated evidence was the initial control input to bank right and place the aircraft 30 degrees nose down (which was followed 39 seconds later by the failed recovery attempt and crash). The time between those two events was unaccounted for.

Channelized attention was judged to restrict the pilot’s spatial awareness during the maneuvers leading up to the crash. The pilot underwent discernible changes in acceleration, attitude, and roll, but did not respond to them. Channelization was found to delay the pilot’s recognition of the aircraft’s altitude and application of corrective actions.

Personal Equipment and Ergonomics

A post-crash assessment of pilot maneuverability within the F-22A cockpit while wearing Category III cold weather gear and NVGs revealed that the equipment’s bulk greatly reduced pilot mobility. The NVGs hit the top of the cockpit canopy and interfered with the pilot’s ability to look from side to side and down at the consoles. In addition, NVGs possess a notoriety for causing channelized attention because of their narrow line of sight. During the post-crash assessment, wearers of the NVGs and cold weather gear needed to shift their torso in the seat while bracing themselves at various points in the cockpit to perform a complete visual scan. The gear also limited tactile sensation, which could lead to inadvertent flight control inputs.

The small, manual pull-ring that activated the EOS was also tested by the investigation team. Although the investigation team was able to activate the EOS in the cold weather gear and NVGs, they stated that the retrieval of the ring would be difficult. Further, if the initial activation failed, which requires tugging on the ring upward then forward with as much as 40 pounds of force, it was also possible to drop the ring between the seat frame and cushion.

Struggling to reach or locate the ring, once dropped, may have resulted in inadvertent flight control inputs due to loss of tactile senses and the bulk of the cold weather gear.

Organizational Training Issues

The pilot involved in the crash, an experienced fighter pilot, was highly trained to handle complex aircraft emergencies



Figure 6. USAF Accident Investigation Board member wearing Category III cold weather gear and NVGs in F-22A cockpit.

and had recently reviewed malfunction procedures during monthly Supervised Emergency Procedure Training. However, the procedure training does not simulate real world, physiological stressors that the pilot may have encountered (i.e., restricted breathing, gravitational forces).

Recovered evidence suggests that the pilot's oxygen mask was in place at the time of the crash. Not having activated the EOS, a likely sensation of suffocation may have contributed to channelized attention.

AFTERMATH

The Pentagon Inspector General investigating the Air Force investigation also deemed human error causal to the mishap; however, civil legal action against the manufacturer has resulted in changes to the design and location of the EOS activation mechanism. The IG investigation was in respect to verifying the USAF Accident Investigation Board's adherence to established investigation procedures. The Air Force has confirmed that over 200 upgraded EOS activation devices have been delivered, and refit of the F-22A fleet at JBER is complete. At the time of this study's publication, F-22 physiological incidents involving the oxygen system continue to be reported and investigated.

RELEVANCE TO NASA

This study was drawn primarily from the USAF legal investigation, performed against the future contingency of legal claims and to assign accountability. Its scope did not include the assessment or validation of design or training requirements; instead, verification of performance as designed and as trained or qualified was within the investigation's purview. The question of preventing recurrence was not released to the public.

Even from this legal vantage point, NASA can draw engineering and safety lessons and benefits. First, a vast array of personal protective equipment (PPE) is currently worn in conduct of NASA missions, from the ocean floor to hydrazine fueling operations to stratospheric flight. The more unforgiving the environment, the more important it becomes not only to

perform normal tasks reliably, but to practice off-nominal tasks to perfection. What if visibility goes to zero? What if breathing is restricted? What if the PPE system malfunctions? The USAF investigation stated that the mishap flight was likely the pilot's first experience with loss of OBOGS oxygen. There was a backup system. For NASA missions, where is the life-saving design margin, in redundant or robust engineering? To what extent has the user been considered in its design or acquisition? Does the PPE conform not only to the user but to the constraints of the workplace?

Second, regarding user qualification and training: can the least-proficient user understand and exploit that full margin of safety on the worst day at work? There are at least three qualifiers to the "Yes I can" answer: yes, if I have the knowledge; yes, if I am physically capable; and yes, if I am proficient enough today at the skills needed today. Each of the three is a perishable commodity that needs checking for high-risk tasks regardless of any protective equipment involved.

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SYSTEM FAILURE CASE STUDY

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