Aviation Investigation Final Report

Location:	Birdseye, Utah	**Accident Number:**	WPR13FA294
Date & Time:	June 27, 2013, 10:20 Local	**Registration:**	N4459R
Aircraft:	Cessna 172	**Aircraft Damage:**	Substantial
Defining Event:	Fire/smoke (non-impact)	**Injuries:**	1 Fatal, 1 Serious
Flight Conducted Under:	Part 91: General aviation - Other work use		

Analysis

This report was modified on August 18, 2015. Please see the docket for this accident to view the original report.

A company that designed and manufactured airborne radar units, primarily for military applications, was using the accident airplane (as well as one other airplane) for some of the airborne development and testing of the externally mounted radar equipment. The pilot was in the left seat and a test engineer, who was not a pilot, was in the right seat. The airplane was equipped with a supplemental electrical power supply system that the company had designed and manufactured to provide electrical power for the radar systems and support equipment on the test flights. Most of the supplemental power supply system was located in the combined baggage area and the area vacated by the removal of the rear seats. In its installed position, the supplemental power supply system was not intended or able to be reached by the pilot or engineer during flight.

About 2 hours into the radar test flight, the test engineer smelled smoke in the airplane. The pilot attempted to locate the source of the smoke and observed an open flame on the supplemental power supply. Because the fire was out of the pilot's or engineer's reach and the airplane was not equipped with a fire extinguisher, the pilot decided to land as soon as possible. During the attempted emergency landing on a road, the airplane struck power lines suspended above the road and then impacted the ground. Detailed examination of airplane and power system components revealed that the fire involved several wires that connected directly to the power system battery and that the fire had spread to the airplane floor carpet.

The supplemental electrical power supply system components included, in part, an automobile-type 12-volt direct current battery, which was encased in a covered, plastic box, and a company-designed and -manufactured hard-plastic power distribution box. The power distribution box was stacked on top of the battery box, and they were secured in place by a ratcheting cargo strap system. In that configuration, two 12- to 14-gauge plastic-insulated wires, one red and one black, were situated and pressed between the top cover of the battery box and the bottom of the power distribution box, and then routed into the distribution box via a single grommeted hole in the bottom of that box. The installation had no provisions for separating or protecting the two wires, and the evidence was consistent with the wires abutting or crossing one another while pressed between the two boxes.

The high-vibration environment of the test airplane caused relative motion between the two boxes and/or the boxes and the wires. That relative motion, combined with the pressure exerted by the boxes on the wires, abraded the insulation of those wires, which then allowed their conductors to contact one another. Because the black wire was connected directly to the negative battery terminal and the red wire was electrically connected to the positive battery terminal, contact of those conductors yielded a direct electrical short. The wires were rated to carry a maximum current of about 45 amperes, and the battery-rated output was 750 amperes. The short circuit resulted in a significant overcurrent in the wires, which caused excessive heating, additional insulation failure, smoke, and fire. Although the pilot did not recall all of the details of the event, the evidence indicated that the fire produced a significant amount of soot and heavy particulate matter, and possibly other physiological irritants.

The wire installation was not in accordance with Federal Aviation Administration (FAA) maintenance guidance, which advised that wire insulation be protected against chafing or abrasion because damage can result in a short circuit. The appearance of the supplemental electrical power supply, particularly its intercomponent wiring, was consistent with that of test-bench equipment, designed to be operated in a stationary environment with minimal or no vibration. No guidance or other documentation regarding the physical installation of the system components in the airplane or the security and protection of the associated wiring was located. A company technician, who was not an FAA-certified aircraft mechanic, reported that he accomplished the original installation of the supplemental power supply a few weeks before the accident; the power supply had accumulated about 13 hours of operation since its installation. The investigation was unable to determine if, how many times, or by whom, the power supply or its components might have been adjusted, moved, removed, and/or reinstalled. It could also not be determined whether the company-contracted aircraft mechanic had provided any installation guidance or whether he had examined, changed, or otherwise contacted or disturbed the original installation, because that mechanic did not respond to requests for information. The installation and arrangement of the affected wires were not in compliance with acceptable practices for aircraft, and the installation presented a serious hazard to flight safety due to the high potential for insulation abrasion and failure, with the resultant unintended electrical path(s).

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

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The operator's improper installation of a supplemental electrical power supply, which caused a short circuit due to inadequate vibration and abrasion protection, which resulted in chafing of the wires, which contacted one another, short-circuited, and caused an onboard fire. Contributing to the accident were the installation of the supplemental electrical power supply system without the supervision of an FAA-certified mechanic, the lack of an onboard means for fire suppression, and the pilot's inability to see the low-conspicuity power lines across the landing approach path until it was too late to take evasive action.

Findings

Personnel issues	Installation - Other
Aircraft	Misc wiring - Incorrect use/operation
Organizational issues	Oversight of maintenance - Maintenance provider
Aircraft	(general) - Not installed/available
Aircraft	Misc wiring - Inadequate inspection
Environmental issues	Visibility - Effect on personnel
Environmental issues	Air quality/dust/smoke - Effect on personnel
Environmental issues	Wire - Contributed to outcome

Factual Information

History of Flight

Prior to flight	Miscellaneous/other
Other	Fire/smoke (non-impact) (Defining event)
Landing	Off-field or emergency landing
Approach-VFR pattern final	Collision with terr/obj (non-CFIT)

On June 27, 2013, about 1020 mountain daylight time, a Cessna 172M, N4459R, was substantially damaged when it struck powerlines and terrain during an attempted emergency landing on a road near Birdseye, Utah. The airplane was owned and operated by IMSAR Aviation, a wholly owned subsidiary of IMSAR, of Springville, Utah. The commercial pilot was seriously injured, and the required crewmember received fatal injuries. The radar equipment test flight was operated under the provisions of Title 14 Code of Federal Regulations Part 91. Visual meteorological conditions prevailed, and no flight plan was filed for the local flight.

According to representatives of IMSAR, the airplane was one of two Cessna 172 airplanes used as platforms for the development and testing of airborne radar systems. The airplanes were based at Spanish Fork-Springville airport (U77), Springville, Utah. IMSAR employed one full time pilot, and occasionally utilized the services of contract pilots. On the morning of the accident, the IMSAR pilot was operating the other company airplane, and a contract pilot was operating the accident airplane. The mission plan was to fly predetermined tracks and/or orbits at a location about 16 miles south of U77, at an altitude of about 8,000 feet, for several hours.

The engine start, taxi, run-up, and takeoff were uneventful. The pilot flew toward the assigned test location of Birdseye via the Spanish Fork Canyon. The IMSAR-required test altitude for this particular flight was 2,500 feet above ground level. The airplane arrived on station over Birdseye and conducted the straight-line track portion of the test program, which took about 2 hours. The pilot then began flying some 360-degree orbit (circling) tracks, remaining near the Birdseye area.

After flying several orbits, the test engineer told the pilot that he smelled smoke. The pilot discontinued the orbiting, and began looking for the smoke and its source. He noticed smoke wafting from under the front seats toward the front of the aircraft, and opened both windows and one vent to evacuate the smoke. He then looked over his right shoulder, towards the rear of the airplane, and observed an open flame about 8 inches high and 4 inches in diameter. The flame was situated on top of one of the test equipment components that were located behind the front seats.

The pilot made the decision to land as soon as possible, and after visually scanning the region below, he decided that landing on the road was the best option. The pilot maneuvered the airplane for a northbound, right-hand downwind leg, and simultaneously broadcast a "mayday" communication on the emergency frequency of 121.5 MHz. He received a response almost immediately from an overflying airliner, and briefly advised the airliner of the situation, providing airplane registration number, location, nature of the problem, and his intentions. The pilot then ceased communicating on the radio, and focused on the landing. He configured the airplane for landing, and set up to land to the south on the road. Just before the planned touchdown, when the airplane was about 30 feet above the road, the pilot visually detected a powerline that was suspended above the road and in his path, and pulled up in an attempt to overfly it. The airplane struck that wire, and then struck other powerlines and terrain. There was no post impact fire. Passers-by came to the aid of the pilot, and contacted emergency services to notify them of the accident.

Pilot Information

Certificate:	Commercial; Flight instructor	**Age:**	66
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	May 8, 2013
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	November 15, 2012
Flight Time:	(Estimated) 2528 hours (Total, all aircraft), 20 hours (Total, this make and model)		

Other flight crew Information

Certificate:	None	**Age:**	50
Airplane Rating(s):	None	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	None	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	None	**Last FAA Medical Exam:**	
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	
Flight Time:	(Estimated) 0 hours (Total, all aircraft), 0 hours (Total, this make and model)		

Pilot

Federal Aviation Administration (FAA) records indicated that the pilot held commercial pilot and flight instructor certificates with single-engine land ratings. According to information provided by the pilot, he had approximately 2,528 total hours of flight experience, which included approximately 2,088 hours in single-engine airplanes, and 20 hours in the accident airplane make and model. He had most recently flown the accident airplane about 1 month prior. His most recent flight review was completed in November 2012, and his most recent FAA first-class medical certificate was issued in May 2013.

According to the pilot, he was a part-time contract pilot who began flying for IMSAR in early February

2013. At that time, as part of his orientation, he was instructed on what IMSAR-related equipment was already installed in the airplane, what equipment would typically be brought to the airplane from the IMSAR office by test personnel, and "generally how to mount and connect that equipment."

His most recent flights for IMSAR were on May 31, 2013, and one of those flights was about a 1-hour familiarization flight in the accident airplane; that familiarization flight was the pilot's first flight in that particular airplane. That flight was "completely normal" and "uneventful," and the pilot "found nothing about the aircraft or the flight to be unusual, particularly challenging or bothersome."

The pilot reported that IMSAR equipment test flights always included 2 persons; 1 pilot and 1 engineer/observer. The pilot was responsible for flying the airplane to the test area, and executing the designated flight test ground tracks, which were depicted on the panel-mounted guidance equipment. The pilot stated that the engineer/observer generally had the responsibility to either perform or assist with the equipment mounting and hookup, and that specific operations of the equipment were the responsibility of the engineer/observer.

The pilot incurred serious impact injuries, but no fire- or thermal-related injuries.

Test Engineer

The test engineer was an engineering employee of IMSAR. He was not a pilot. According to documentation provided by IMSAR, he had flown as the test engineer in the accident airplane twice on June 14, and once on June 18. The durations of those flights were 4.0, 2.5, and 2.0 hours, respectively. The pilot for all three of those flights was the IMSAR chief pilot.

The test engineer did not incur any thermal injuries; his death was impact-related.

Aircraft and Owner/Operator Information

Aircraft Make:	Cessna	**Registration:**	N4459R
Model/Series:	172 M	**Aircraft Category:**	Airplane
Year of Manufacture:	1974	**Amateur Built:**	
Airworthiness Certificate:	Restricted (Special)	**Serial Number:**	17263201
Landing Gear Type:	Tricycle	**Seats:**	2
Date/Type of Last Inspection:	June 2, 2013 Annual	**Certified Max Gross Wt.:**	
Time Since Last Inspection:	13 Hrs	**Engines:**	1 Reciprocating
Airframe Total Time:	2111 Hrs at time of accident	**Engine Manufacturer:**	LYCOMING
ELT:	C91 installed	**Engine Model/Series:**	0-320 SERIES
Registered Owner:	IMSAR Aviation LLC	**Rated Power:**	160 Horsepower
Operator:	IMSAR Aviation LLC	**Operating Certificate(s) Held:**	None

FAA information indicated that the airplane was manufactured in 1974 as Cessna serial number 17263201, and was equipped with a Lycoming O-320 series engine. The airplane was purchased by IMSAR Aviation in February 2013, and modified for mounting and testing of the radar equipment. IMSAR Aviation utilized the services of an independent FAA mechanic with an inspection authorization rating for some of the modifications. The airplane was registered to IMSAR in the restricted category.

At the time of the accident the airplane had accumulated approximately 2,111 hours total time in service. Its most recent annual inspection was completed on June 2, 2013, and it had accumulated about 13 flight hours since that inspection.

Review of the airplane flight logs indicated that the airplane was not operated during the period from February 23, 2013, to May 30, 2013, inclusive. The airplane flew one flight of 1.0 hours on May 31. It then flew two flights on June 14, and one each on June 17 and June 18. The next flight was the accident flight. The respective durations of those five pre-accident flights were 1.0, 4.0, 2.5, 1.7, and 2.0 hours, for a total time of 11.2 hours.

The certification basis for the airplane required that the cabin furnishings, including the floor carpet, be "flame resistant." The regulations and certification criteria defined a "flame resistant" material as material "which will not support combustion to the point of propagating, beyond safe limits, a flame after the removal of the ignition source." The certification basis did not include smoke, fume, or particulate criteria.

There was no fire extinguishing equipment on board, nor was a fire extinguisher FAA- or IMSAR-required equipment for the flight. FAA requirements for general aviation aircraft certificated subsequent to the certification of the accident airplane mandated equipping those aircraft with fire extinguishers.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	PVU,4497 ft msl	**Distance from Accident Site:**	20 Nautical Miles
Observation Time:	09:55 Local	**Direction from Accident Site:**	360°
Lowest Cloud Condition:	Clear	**Visibility**	15 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	3 knots / None	**Turbulence Type Forecast/Actual:**	/
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.25 inches Hg	**Temperature/Dew Point:**	26°C / 9°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Springville, UT (U77)	**Type of Flight Plan Filed:**	None
Destination:	Springville, UT (U77)	**Type of Clearance:**	None
Departure Time:	08:00 Local	**Type of Airspace:**	Unknown

The 0955 automated weather observation at an airport located about 20 miles north of the accident site included variable wind at 3 knots, visibility 15 miles, clear skies, temperature 26 degrees C, dew point 9 degrees C, and an altimeter setting of 30.25 inches of mercury.

According to astronomical data from the National Oceanic and Atmospheric Administration, at the accident location about the time of the accident, the sun's azimuth was about 98 degrees from true north, and its elevation was about 47 degrees above the horizon.

Airport Information

Airport:	Spanish Fork-Springville U77	**Runway Surface Type:**	Asphalt
Airport Elevation:	4529 ft msl	**Runway Surface Condition:**	Dry
Runway Used:		**IFR Approach:**	None
Runway Length/Width:		**VFR Approach/Landing:**	Forced landing;Precautionary landing;Traffic pattern

Wreckage and Impact Information

Crew Injuries:	1 Fatal, 1 Serious	**Aircraft Damage:**	Substantial
Passenger Injuries:		**Aircraft Fire:**	In-flight
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 Fatal, 1 Serious	**Latitude, Longitude:**	39.907222,-111.54972(est)

The accident site was located about 15 miles south of U77. The airplane was examined on-site by FAA and IMSAR personnel on the day of the accident, and then by FAA, NTSB, and Cessna Aircraft Company personnel the day after the accident.

The pilot was attempting an emergency landing to the south on US Highway 89, a two-lane north-south asphalt road. The road is situated in a north-south valley about 50 miles south of Salt Lake City. The approximate impact location was at an elevation of about 5,520 feet above mean sea level. The airplane came to rest on terrain about 15 feet lower than, and about 25 feet west of, the road.

On-scene evidence was consistent with the airplane striking two separate sets of powerlines. The first set was oriented east-west, transversely across the road, and consisted of two lines. The second set was oriented north-south, parallel to the road, and consisted of four lines. The two powerline sets shared a common weathered-wood support pole located about 40 feet west of the roadway centerline. That pole was one in a series of poles that paralleled the road, and which supported the four-powerline group. The poles in that group were spaced about 350 feet apart. The eastern end of the transverse powerline set was supported by another weathered-wood pole. That pole was situated in a field, and was located about 250 feet east of the road.

The airplane first struck and broke the highest powerline in the transverse (east-west) set. That fractured powerline was situated about 28 feet above the road. It had an overall diameter of 0.316 inches, and the nominal rated tensile strength of the cable was 2,850 pounds. A second similar cable in the transverse set, which was situated about 23 feet above the road, was not struck, and remained intact.

The airplane then struck at least two separate cables that were in the four-line set that paralleled the roadway on its west side. The uppermost cable was situated about 35 feet above the road, The cable was significantly damaged but not completely fractured; all but one strand of that cable were "bunched" at the south end of an approximately 18-foot section, consistent with them being fractured and then compressed along the single intact strand by the airplane. The overall cable diameter was 0.398 inches, and the nominal rated tensile strength of the cable was 4,380 pounds.

A second similar cable, situated about 4 feet closer to the road than, and 3 feet below, the top cable, was completely fractured. Two other cables in that group were not fractured but displayed electrical arcing burns in the vicinity of the bunching. None of the powerlines were marked or highlighted with any devices (such as balls) to increase their visual conspicuity, nor were they required to be.

Cable and airplane witness marks were consistent with the nose landing gear first striking the transverse cable, and the right wing and main landing gear subsequently striking the parallel cables. The airplane came to rest about 270 feet south of the transverse cable strike location. The airplane came to rest inverted, with the fuselage oriented about 45 degrees from horizontal. The approximate at-rest heading was 220 degrees magnetic. Aside from multiple small window and plastic fragments, no components had separated from the airplane.

The engine was displaced up, aft, and left in the airplane axis system. The two blade fixed pitch metal propeller remained attached to the engine. Cockpit occupiable volume was significantly compromised forward of the front seats. The right wing displayed leading edge crush damage at the outboard-most 3 feet of its span. The left wing exhibited tip crush and fragmentation damage. The flaps were found extended to the full-down landing position of 40 degrees. Both wings and both flaps exhibited crush damage in the lateral direction in their aft inboard regions, and the upper aft fuselage exhibited corresponding crush damage in the region of the rear window. The fuselage exhibited slight buckling towards the aft end of the cabin. The aft fuselage, tailcone, and empennage were essentially undamaged.

All airplane components, including all flight controls, were accounted for at the site. Control cable continuity was established throughout the airplane.

A Lowrance AIRMAP 1000 GPS, was recovered from the wreckage and sent to the NTSB Recorders Laboratory in Washington, DC for data download. Damage to the device, plus the unit's data storage protocols, prevented development of an airplane flight track time history. Additional details are provided in a separate report in the public docket for this accident.

Examination revealed that a supplemental electrical system installed to provide power for the radar equipment and associated test equipment had overheated and began to burn. No evidence of overheating or fire was observed on any wiring or electrical components of the airplane itself; thermal damage was confined to the operator-installed electrical system and airplane furnishings (carpet, sidewalls, etc). The airplane and components were recovered and transported to a secure facility for additional examination.

Refer to the public docket of this accident for additional details.

Communications

The departure airport, U77, was a non-towered airport; pilot radio communications to coordinate their movements were conducted on a dedicated common traffic advisory frequency (CTAF). Aside from the normal radio transmissions on CTAF to depart U77, the pilot did not use the airplane radios to communicate any air traffic-related information, nor was he required to. During the flight, he and/or the test engineer occasionally communicated via radio with IMSAR personnel in support of the test.

The pilot stated that while he was establishing the airplane on the downwind leg for his emergency landing on the road, he made one or more brief "mayday" transmissions on the standard emergency frequency, which was received by and responded to by a passing commercial airline flight. The pilot relayed his N-number, situation, location, and intentions to the airline flight crew, who then relayed the information to an air traffic control facility. The Cessna pilot then focused on flying and landing the airplane, and did not make any subsequent radio communications.

Fire

An onboard open-flame fire occurred in the mid-aft cabin of the airplane. The fire involved the operator's supplemental power supply, the synthetic material carpet on the airplane cabin floor, and the synthetic material cargo tiedown straps. The fire produced a significant amount of smoke and dark, airborne soot and/or plastic particulate matter, and melting or burning plastic also produces fumes which are physiological irritants. The fire did not damage or affect any of the engine or flight controls, or adversely affect the structural integrity of the airplane.

The fire and the involved equipment were physically beyond the reach of the test engineer and the pilot. The airplane was not equipped with a fire extinguisher. For those reasons, neither the pilot nor the test engineer was able to conduct any activities to suppress or extinguish the fire. The fire did not continue to burn after impact.

Additional Information

IMSAR Equipment

IMSAR was a designer and manufacturer of synthetic aperture radar systems that were primarily intended to be used on airborne platforms, primarily by the Department of Defense (DoD), and often as externally-mounted pods. The company used its two Cessna airplanes as low-cost platforms for portions of the airborne development and testing of the radar equipment. In order to provide for the electrical power needs of the various radar systems and support equipment being tested or used on the Cessnas, and also to enable those devices to be electrically isolated from the airplanes' electrical systems, IMSAR designed and manufactured two similar supplemental power supply systems, one for each of its airplanes. For both airplanes, the rear seats had been removed, and the bulk of the power supply system was located in the continuous space of the airplane baggage area and the area vacated by the removal of those seats.

The supplemental power supply system was designed to provide 12VDC, 28VDC, and 120VAC to the radar and support equipment on the subject airplane. Primary power supply system components included an automobile-type 12VDC battery, an "isolation unit/automatic charging relay," a battery switch, a network modem/router, an inverter, a "remote switch box," a cockpit-mounted circuit breaker panel, and a "power distribution box." The system was partially connected to the airplane electrical system.

The power distribution box provided multiple airplane-independent power outlets for 12VDC and 28VDC. The box consisted of a hard, stiff plastic shell with a hinged cover, which encased a step-up transformer, a bus block, and other electronics. Opening of the box cover provided access to the multiple 12VDC and 28VDC ports for the radar equipment. The system was powered by its 12VDC battery, which was charged by the airplane electrical system as needed. The inverter was used to provide 120VAC power to laptop computer(s) used by the onboard test engineer. The remote switchbox was to be used in flight to control power to the various 12VDC and 28VDC outlets, and the cockpit-mounted circuit breaker panel was to be used to control electrical power between the airplane and the supplemental power system. The remote switchbox and the circuit breaker panel were the only two components that could, or were intended to, be readily reached by the test engineer during flight.

The radar units were typically carried on pods which attached to hardpoints on the wing, and were connected to the supplemental power supply and cockpit monitoring and control equipment by an IMSAR-designed and fabricated wire harness. The airplane baggage door was also modified with an external mount rack for other radar equipment. Refer to the public docket of this accident for additional details.

Wire Insulation Damage Protection

According to the Aviation Maintenance Technician Handbook (FAA H-8083-31) "Wires and wire groups should be protected against chafing or abrasion in those locations where contact with sharp surfaces or other wires would damage the insulation, or chafing could occur against the airframe or other components. Damage to the insulation can cause short circuits, malfunction, or inadvertent operation of equipment."

An operating piston-engine general aviation airplane is a high-vibration environment, which provides the mechanism for potential mechanical damage to improperly secured or improperly protected wiring. In order to minimize or prevent mechanical damage, wires should be supported by suitable clamps or other devices at appropriate intervals to preclude relative motion and chafing. Wires should also be prevented from being pinched or crushed, which can damage or fail the insulation.

Equipment Design and Fabrication Requirements

The radar equipment and the supplemental power supply systems were designed and fabricated at the IMSAR facility by IMSAR personnel. Because most of the radar systems were intended for DoD airborne applications, they were designed and manufactured to the applicable specifications and industry standards for the vibration environment of the intended application.

In contrast, the supplemental power supply was an internal IMSAR product that was to be flown on IMSAR owned and operated aircraft, and was subject only to IMSAR design and fabrication standards and requirements. The appearance of the supplemental power supply was consistent with that of test-bench equipment, designed to be operated in a benign, stationary environment, with minimal or no vibration. The power supply design and fabrication information that IMSAR provided to the investigation did not contain any specifics or references regarding any vibration envelope requirements, or any wire insulation abrasion resistance requirements.

Equipment Installation Information

According to the radar technician who fabricated the supplemental power supply, he conducted the initial installation of the system in the airplane a few weeks before the accident. The technician was not a FAA certified aircraft mechanic. No guidance or other documentation regarding the physical installation of the system components in the airplane, or the security and protection of the associated wiring was provided by the operator. Correlation with the airplane flight logs indicated that the installation occurred either just before May 31, 2013, or during the period between May 31 and June 14, 2013.

Most of the large power supply system components were not permanently affixed to the airplane, but typically tended to remain installed in the airplane between flights. While the component arrangement inside the airplane remained essentially constant, how many times, or by whom it might have been adjusted, moved, or removed and reinstalled could not be determined. Because the FAA-certified aircraft mechanic who was contracted by IMSAR to assist in certain modifications to the airplane did not make himself available to the NTSB investigator, it could not be determined if he generated any installation guidance, or whether he had examined, changed, or otherwise contacted or disturbed the original installation. While it was determined that the mechanic did not examine the installation on the morning of the accident, it could not be determined whether he examined the power supply in its accident flight configuration.

For the accident flight, the battery was encased in a covered, plastic battery box. The plastic power distribution box, with the modem and battery switch mounted to its cover, was stacked on top of the battery box, and that stack was secured in place by a ratcheting cargo strap system. In that configuration, two 12- to 14-gauge plastic-insulated wires, one red and one black, were situated and pressed between the top cover of the battery box and the bottom of the power distribution box, and then routed into the distribution box via a single grommeted hole in the bottom of that box. The installation had no provisions for dedicated positioning or separation of those wires, and the evidence was consistent with the wires abutting or crossing one another.

The black wire (designated B-1 for the investigation) was connected directly between the negative terminal of the battery and a terminal on the bus block inside the distribution box. One end of the red wire (designated R-1 for the investigation) was electrically connected to the positive battery terminal via the battery switch; the other end connected to a terminal on the transformer inside the distribution box. Another similar red wire, designated R-3, attached to the battery switch, and was draped over the top and down the side of the power distribution box, and then laid on the airplane floor carpet, where it connected to the isolator.

The isolator, inverter, and the remote switchbox were loose-laid on the carpeted floor of the airplane, while the laptop was held by the test engineer. The circuit breaker panel and the radar pod wiring harness were affixed more permanently to the airplane. That harness provided electrical power from the supplemental power system to the radar pod, and data between the radar pod and the test engineer's computer.

Accident Morning Activities

According to the pilot, unlike the power supply, the radar pods and test equipment would tend to be located at the IMSAR facility unless the hardware was being tested on the airplane.

Also according to the pilot, he was asked by the IMSAR Chief Pilot about a day or two prior to conduct this particular flight. In the pilot's experience with IMSAR, that notification lead time was typical.

On the morning of the accident, the pilot arrived at U77 at 0630, and, while waiting for the test engineer to arrive, preflighted both IMSAR airplanes, because he was not advised which airplane he would be operating. The assigned test engineer arrived about 0700 with the test equipment, and he and the pilot installed the test radar pod on the wing of the accident airplane. The supplemental power supply was already installed and secured in the airplane.

System Examination Observations

The battery box, power distribution box, modem, battery switch, isolator, inverter, remote switch box, and circuit breaker panel, as well as their associated wiring, were sent to the NTSB materials laboratory for examination and testing.

The modem, remote switch box, circuit breaker panel, and battery switch were thermally undamaged. The bottom of the isolator sustained minor thermal damage. The battery box and the power distribution box were significantly fire damaged. None of the components exhibited any significant impact damage.

Aside from some moderate damage to its insulation near where the positive input lead entered the inverter, the inverter was free of thermal damage. The inverter sustained some minor impact related internal damage, but a functional test was performed, and the inverter operated per design. The battery switch did not have any internal damage, and a functional test indicated that the switch operated per design. Because the modem and the remote switch box and their wiring were undamaged, those components were not tested.

The circuit breaker panel sustained impact damage. The toggle switch of the 40A breaker was fracture-separated. The breaker 'button' fell out of the other breaker housing. The as-found wiring was consistent with IMSAR design drawing, and neither breaker showed evidence of any thermal distress. Neither breaker was tested.

The exterior surfaces of one lower corner of the power distribution box shell, plus a portion of the cover, sustained sooting, discoloration, and blistering. The damaged bottom exterior portion of the box shell included the grommeted hole. The interior of the box shell was nearly undamaged; only some minor sooting and localized wall discoloration were present. Functional testing of the step-up transformer indicated that the unit operated satisfactorily. Pin connections and wire routing was determined to be per IMSAR design.

About 15 percent of the battery box cover, and about 5 percent of the battery box, were consumed by fire. Several additional square inches of both the cover and the box exhibited significant thermal damage, and the remainders of those components bore some sooting and other indications of fire exposure.

All the wires that were electrically connected to the positive battery terminal sustained significant thermal damage (melting or material loss) to their insulation. Those wires were designated as R-1, R-2, R-3, R-4, and R-5 for the investigation. For the flight, the R-2 and R-3 wires laid unrestrained on the airplane floor carpet, and the carpet sustained burn patterns which were congruent with the routing of those two wires.

The insulation on the B-1 black wire sustained significant thermal damage. The B-1 wire, which connected directly to the negative terminal of the battery, was the only negative wire to sustain thermal damage. The B-1 wire had been separated in mid run, and examination of the separation point indicated that the separation was not consistent with an electrical arcing failure. No other wires exhibited thermal damage.

When situated in the airplane, the fire-affected region of the power distribution box was the forward, right, lower corner. When the battery box and the power distribution box were arranged in their relative in-flight positions, the location of the most significant battery box and battery box cover damage corresponded to the damage location of the bottom of the power distribution box. That damage location also corresponded to the region where the B-1 and R-1 wires were sandwiched between the two boxes. The distribution box cover damage was located where the R-2 and R-3 wires from the battery switch draped across the cover. The airplane carpet under the isolator sustained significant thermal damage, including complete burn through.

Review of the wiring configuration revealed that the R-1 and B-1 wires were in close physical proximity or direct contact in two separate locations. The first location was inside the power distribution box, just prior to where the wires exited the grommeted hole. In their as-found condition at that location, the insulation from both wires had melted, separated from portions of the copper conductors, and fused together. The conductors from both were heavily sooted or burned. Damage precluded determination of whether the wires were in contact at that location prior to the fire and accident, and if so, with what force.

The second location that the R-1 and B-1 wires were in close physical proximity or direct contact was where they exited the grommeted hole, and were sandwiched between the bottom of the distribution box and the top of the battery box. Damage levels to the battery box, and the wires and their insulation, precluded determination of whether the wires were in contact at that location prior to the fire and accident, and if so, with what force.

The evidence was consistent with the supplemental power supply being exposed to a minimum of about 13 hours in the operating airplane. That vibration environment provided a mechanism for relative motion and mechanical abrasion of the insulation of any wires that were in contact either with one another, or with other components. Factors that affect the abrasion rate include the degree of relative motion, and the force of the contact.

Wire Insulation

Observations and wire labels indicated that the R-1, R-2, R-3 and B-1 wires were 12- to 14-gauge, and sheathed in PVC (polyvinyl chloride) soft plastic insulation. The insulation was rated for 105-degree C service.

Testing by the Cessna materials laboratory was accomplished on undamaged red and black insulation samples to confirm the insulation type and characteristics. The insulation was confirmed to be PVC. White smoke was produced between 235 and 349 degrees C, and again between 449 and 477 degrees C. Thermal degradation in air of both insulation samples was complete at approximately 593 degrees C. The insulation did not display a definite melting point when tested between about 38 and 199 degrees, but became soft at approximately 152 degrees C.

Wire Current Capacity Information

When a current is introduced in a conductor, heat is generated due to the electrical resistance of the conductor. Increases in current result in increased generation of heat. Therefore, in order to prevent overheating and insulation failure, maximum current capacity values have been established for wires. Maximum current capacity values are a function of several variables, including wire gauge, wire length, system voltage, insulation type, and whether the wire is contained in a bundle.

According to FAA guidance, in 12- to 14-volt systems, short runs of non-bundled 14 gauge multistrand conductors would be capable of safely handing a maximum current of about 33 amperes. That value would increase to about 45 amperes for a 12-gauge conductor. The battery in the supplemental power supply had a rated output value of 750 amperes.

Applied current in excess of a wire's rated capacity will result in overheating of the conductor, which can result in insulation failure, smoke, and /or fire. Insulation failure can in turn cause electrical shorts or other malfunctions or failures.

Mechanically- or thermally-induced failure of the insulation can result in contact of previously-separated conductors. Contact of the conductors from any of the above-mentioned "R'" wires and the conductor of the B-1 wire would result in a direct electrical short, which in turn would result in a current flow limited only by the battery output and the physical capacity of the conductors.

Administrative Information

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Original Publish Date:	August 5, 2015
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=87315