NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Western Pacific Region

ELECTRICAL POWER SUPPLY EXAMINATION

NTSB Accident: WPR13FA294
Accident Date: June 27, 2013

Examination Date: January 16/17, 2014

This document contains 18 embedded images

A. ACCIDENT

Location:	Birdseye, UT
Date:	June 27, 2013
Aircraft:	Cessna 172, N4459R, Serial # 17263201
NTSB IIC:	Michael Huhn

B. EXAMINATION PARTICIPANTS:

Michael Huhn
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C. SUMMARY

The operator (IMSAR, Inc) was a private company which designed and manufactured radar systems. IMSAR designed, manufactured, and installed a supplemental electrical power supply system on the accident airplane in order to support radar development flights. The system was designed to provide 12VDC, 28VDC, and 120VAC to company radar components and laptop computer equipment on the subject airplane. The system was partially connected to the airframe electrical system.

Most of the system components were removed from the wreckage and shipped to the NTSB materials laboratory in Washington DC.

Additional documentation is provided in a separate Materials Lab report.

The examination found no evidence of failure of any electrical component. All components that were function-checked operated normally.

D. SYSTEM DESIGN and COMPONENTS

1.0 Synoptic Description

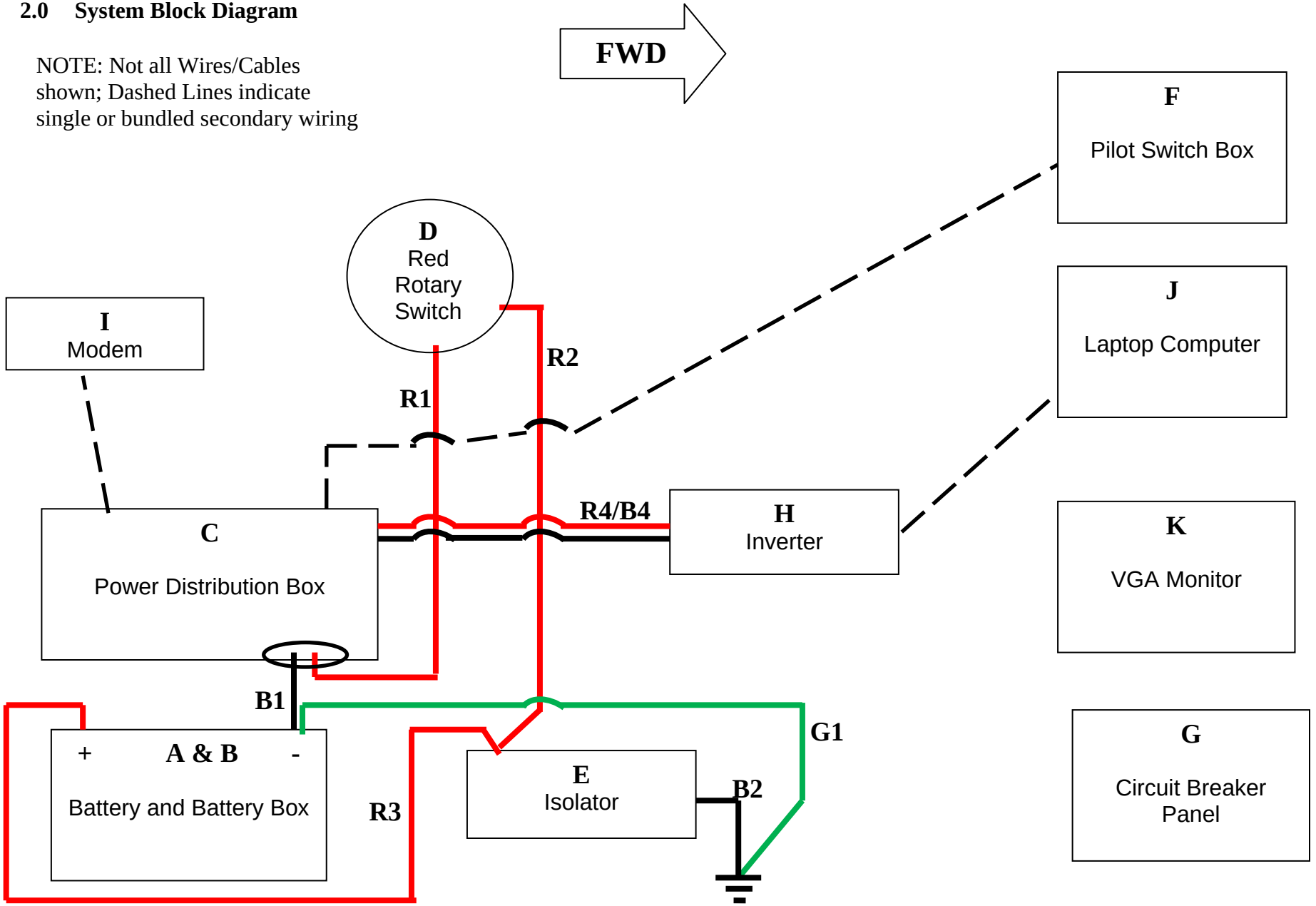
The rear seats of the airplane had been removed, and the bulk of the power supply system was located in the continuous space of the airplane baggage area and that vacated by the seats. Most of the large system components were not permanently affixed to the airplane; some were secured by a ratcheting cargo strap system, while some were loose-laid on the carpeted floor of the airplane. One circuit breaker panel and some wiring which led to the radar components were affixed more permanently to the airplane.

Primary components included an automobile 12VDC battery, a "power distribution box" with multiple 12VDC and 28VDC ports, an "isolation unit/automatic charging relay," a battery switch, a network modem, an inverter, a "remote switch box" and a cockpit-mounted circuit breaker panel.

The design concept/intent was to provide multiple power outlets for 12VDC and 28VDC for the radar equipment. The system was powered by the 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. These were the only two components that were intended to, or could be, reached readily by the test engineer in flight

2.0 System Block Diagram

NOTE: Not all Wires/Cables shown; Dashed Lines indicate single or bundled secondary wiring



3.0 As-Found Component Description

The team reconstructed the mechanical placement of the components using photos and burn marks, and documented the layout with photographs and drawings.

ID for Exam Purposes	Component Name(s) (Common names)	Component Description (approx dims, inches)	Function	Condition & Remarks
A	Battery (House battery)	12v gel cell battery (14x11x10) Located inside 'B'. OPTIMA Yellowtop pn YEL 34/78	12VDC to 'C' via Isolator E	Found outside 'B'. Partially draped with re-solidified plastic from 'B' Not returned to DC lab for exam.
B	Battery Box	Black plastic box w/ removable cover (15x12x11)	Housed 'A'	Partially melted/burned, particularly near positive battery terminal area
C	Power distribution box; (Gray box; Breakout box)	Gray plastic box w hinged cover. Multiple jacks inside (15x12x8), 3 cannon plug attachments on exterior (fwd and aft left, plus aft) Positioned atop 'A/B'	Provide multiple 12VDC and 28VDC outlets	Thermal damage, resolidified red wire insulation and sooting on bottom near hole for power-in leads
C-1	Step up unit	Black solid state unit inside C (2.5x2.2x1) ACON Inc p/n MH 50S1228TS	Convert 12VDC to 28VDC	Visually undamaged
C-2	Negative Buss Bar	Inside C (2.5x1.5x1)	Buss bar	Undamaged
C-3	Relay breadboard	Inside C (4x6x1)	Controls power to individual 12/28VDC power outputs (via remote switchbox F)	Undamaged
D	Battery Switch (Red switch)	Red rotary switch. (3"diam, 2" high) Bolted to top of 'C'. Blue Sea Systems 5511E	Isolate battery 'A' from power supply system	Reportedly turned to OFF by first responders

ID for Exam Purposes	Component Name(s) (Common names)	Component Description (approx dims, inches)	Function	Condition & Remarks
E	Isolator; Relay	Black plastic box (2x2x3) Unsecured on airplane floor. Blue Sea Systems 7610	Separate airplane and supplemental power supplies	Two red wires had insulation melted/charred away
F	Remote Switch Box (Pilot switch box)	Gray plastic box switches and clear plastic guard (4x4x4) Test engineer accessible	Enables test engineer to control power to power/depower 12VDC and 28VDC ports in 'C'.	Appeared undamaged
G	Circuit Breaker Panel	Mounted below airplane instrument panel	To control electrical power between the airplane and the supplemental power system	Two breakers (40A and supposed 5A per dwg – Wood Electric S-1360-5L 435-205-105)
H	DC-AC inverter	Yellow/Black plastic box (4x10x2) Unsecured on airplane floor PowerDrive 1500	Convert 12VDC to 120VAC for laptop etc	Impact damage to case
I	Wireless modem	Black plastic box. (1x6x6) Bolted to top of 'C'	Transmits data to/from ground	Some thermal damage and re-solidified red wire insulation
J	Laptop computer	Loose, with test engineer	Used by test engineer	Not returned to DC lab for exam
K	VGA pilot monitor	Monitor (4x6x1)	Used by pilot for track guidance	Not returned to DC lab for exam

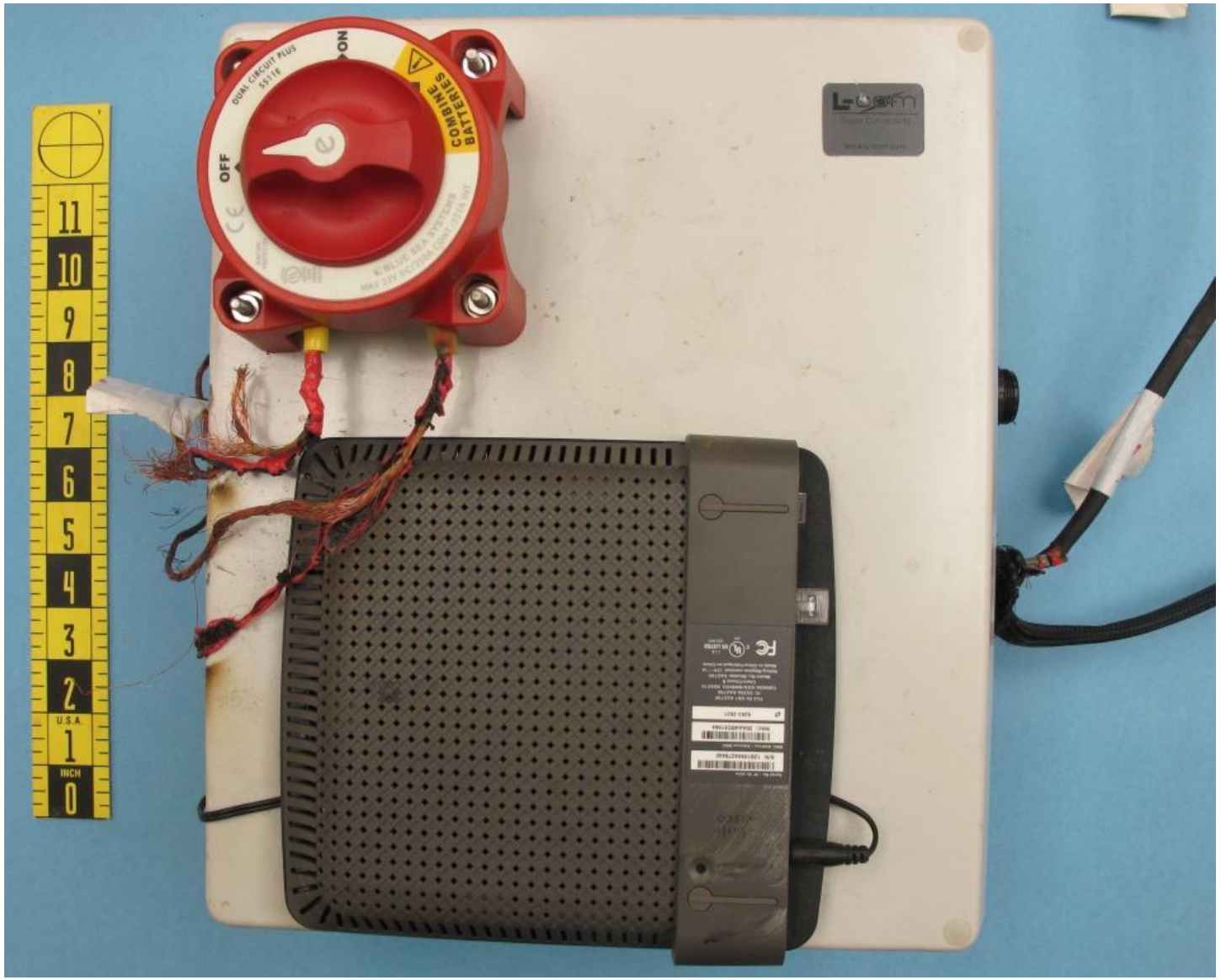


Figure 1 - Top View of Power Distribution Box, With Red Switch and Modem

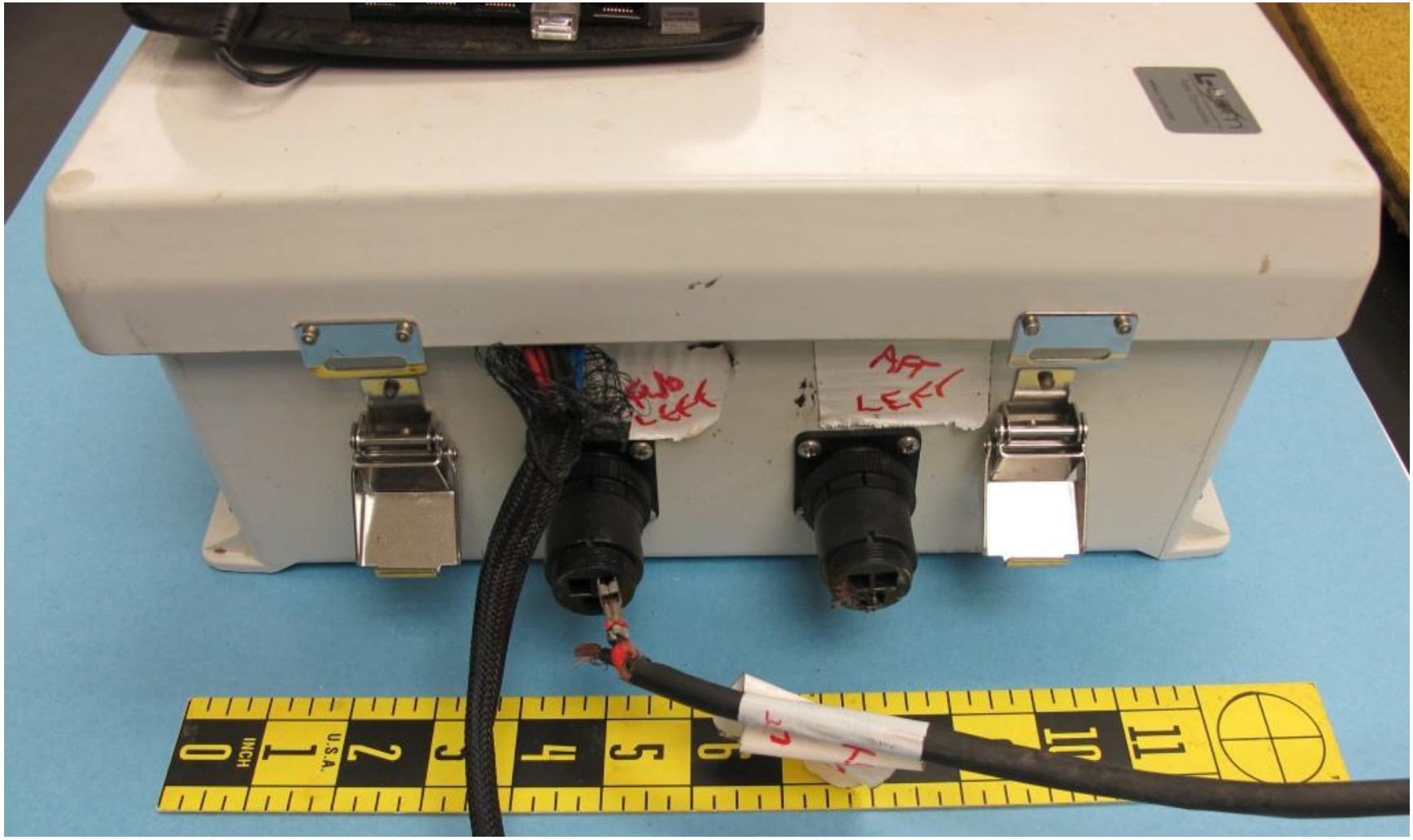


Figure 2 - Left Side of Power Distribution Box

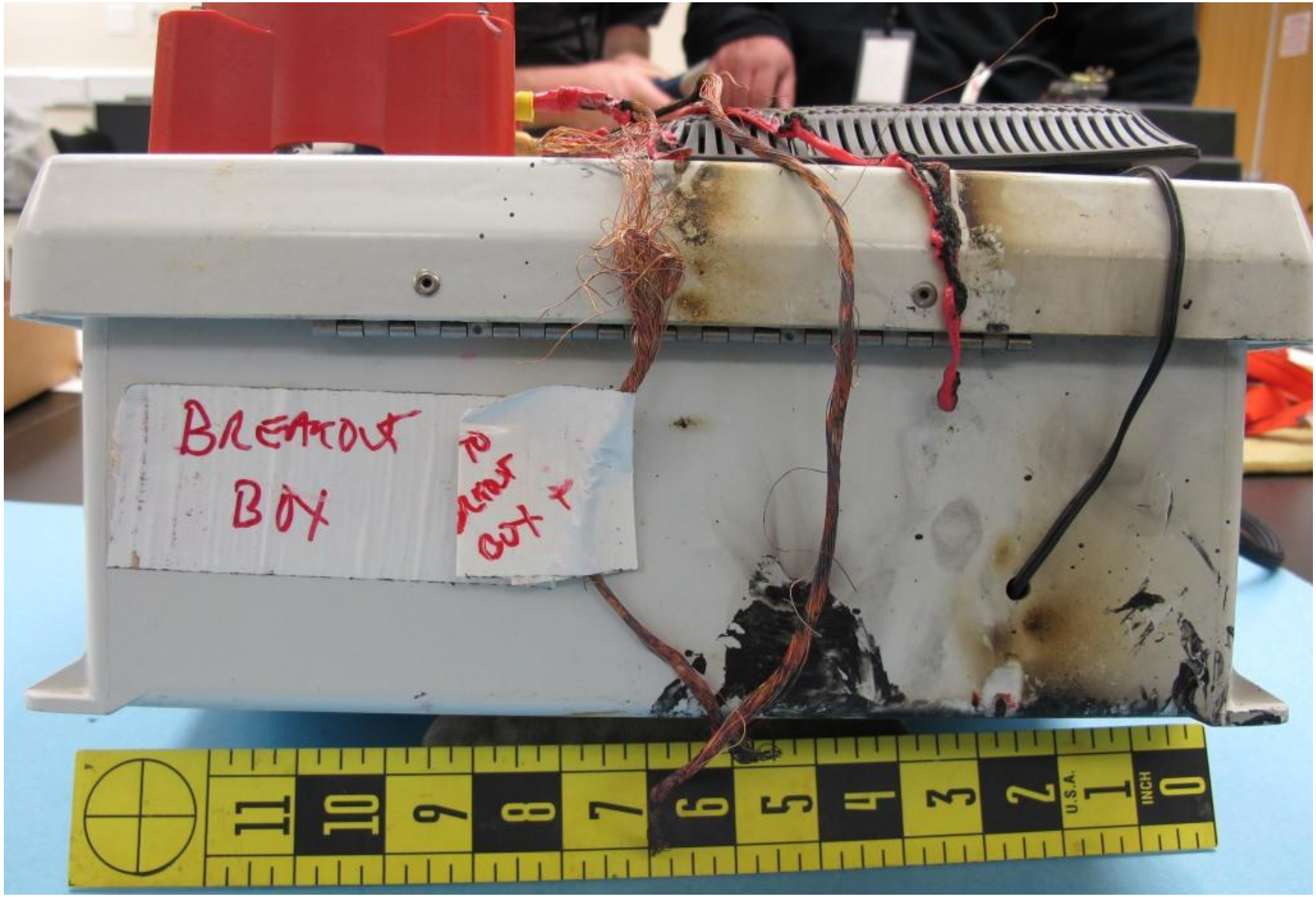


Figure 3 - Right Side of Power Distribution Box

Figure 4 - Bottom of Power Distribution Box

Figure 5 - Closeup of Grommeted Hole in Bottom of Power Distribution Box

Figure 6 - Top View of Battery Box

Figure 7 - Front Side of Battery Box

Figure 8 - Closeup of Front Side of Battery Box Melted Area

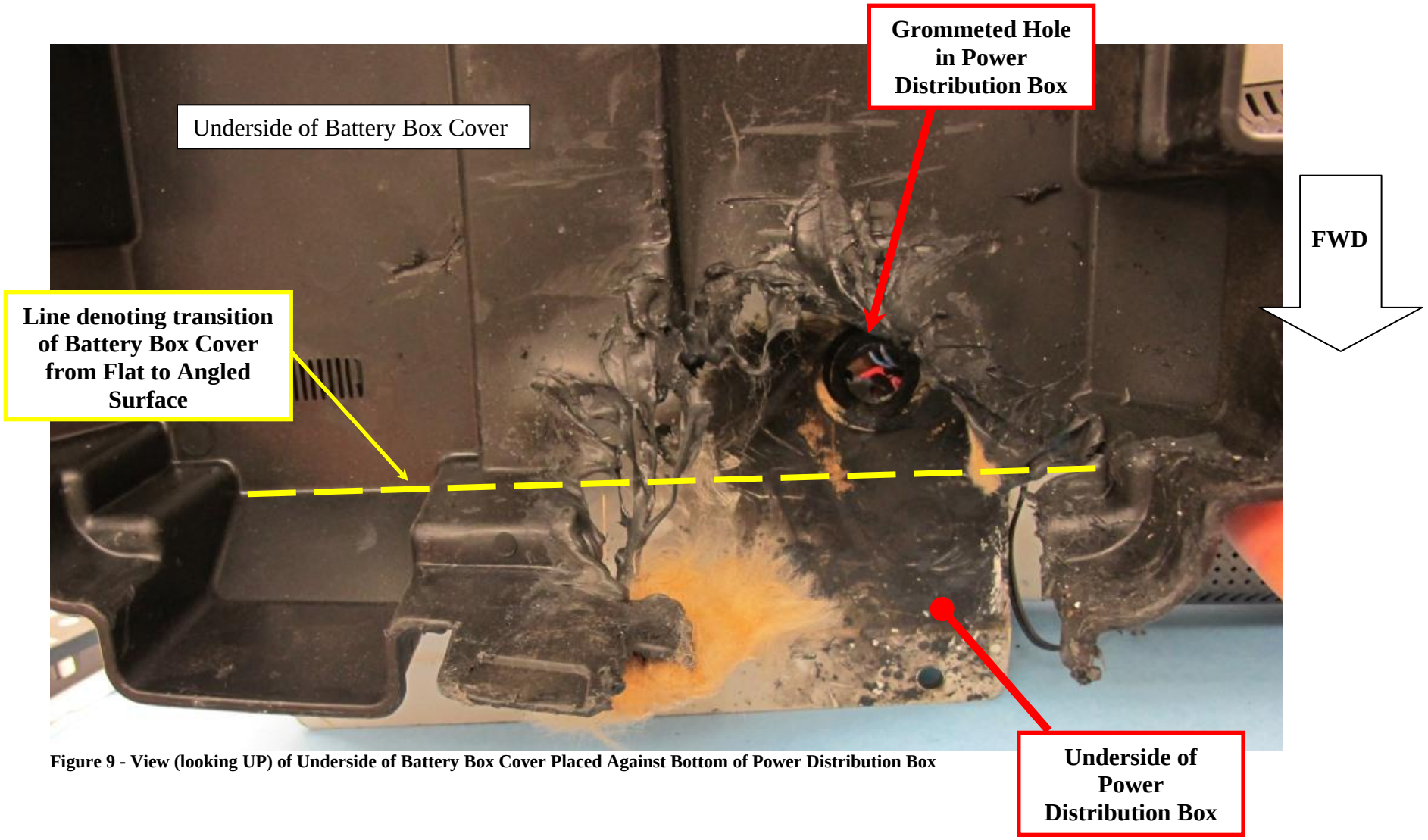


Figure 9 - View (looking UP) of Underside of Battery Box Cover Placed Against Bottom of Power Distribution Box

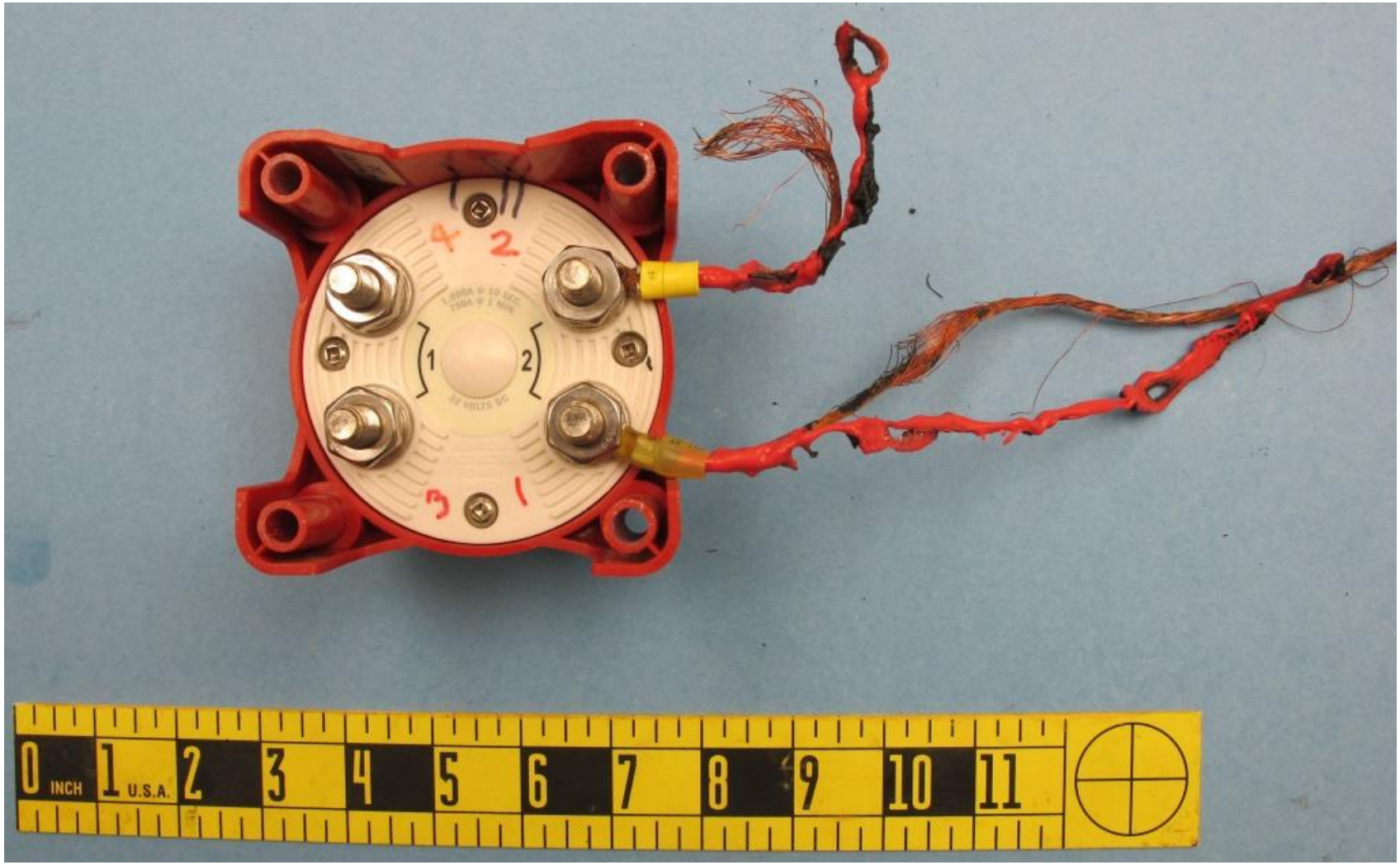


Figure 10 - Underside of Red Switch (with terminal numbers)

Figure 11 - Negative Battery Terminal and Lead

Figure 12 - Positive Battery Terminal and Lead

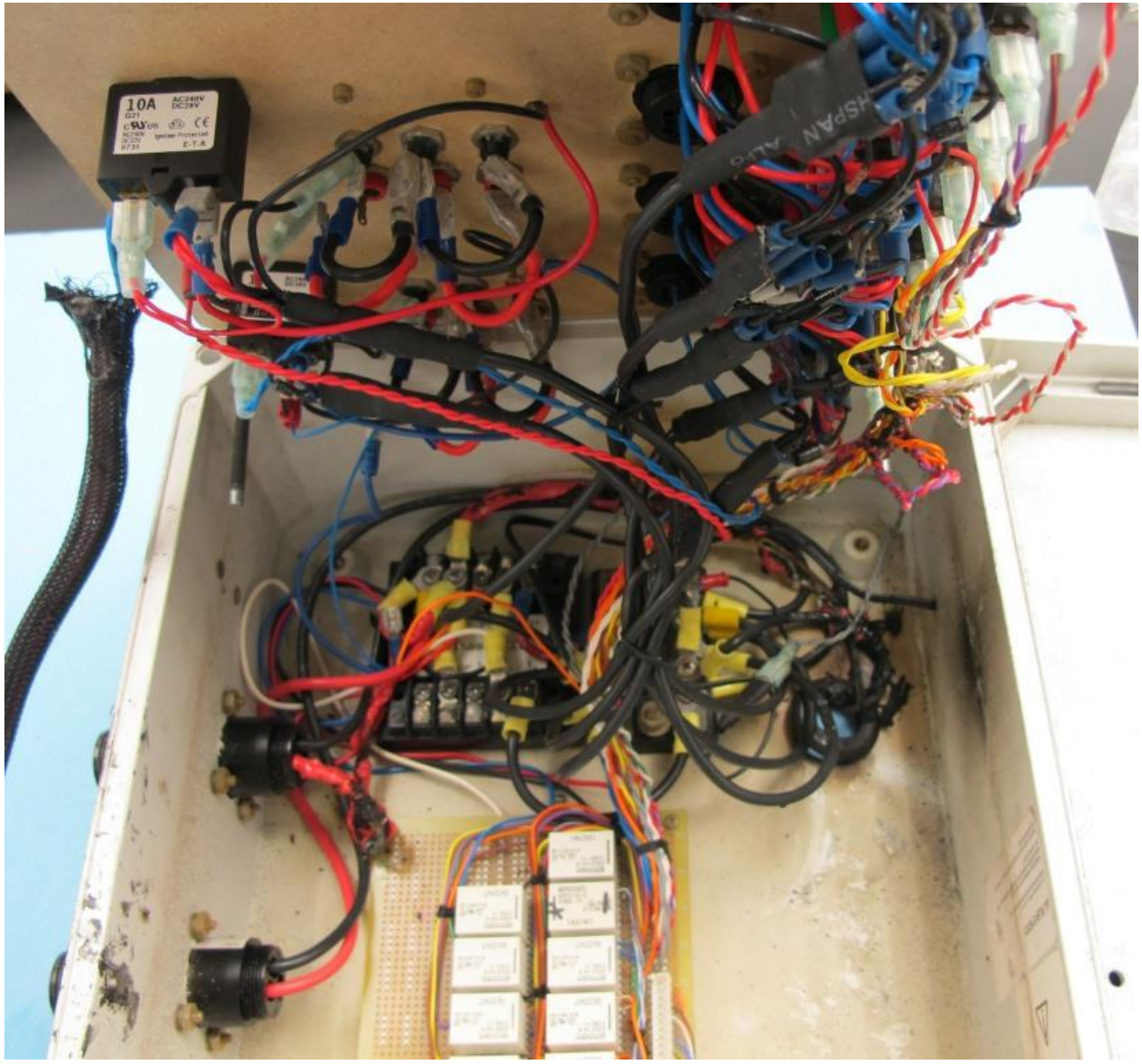


Figure 13 - Inside of Power Distribution Box

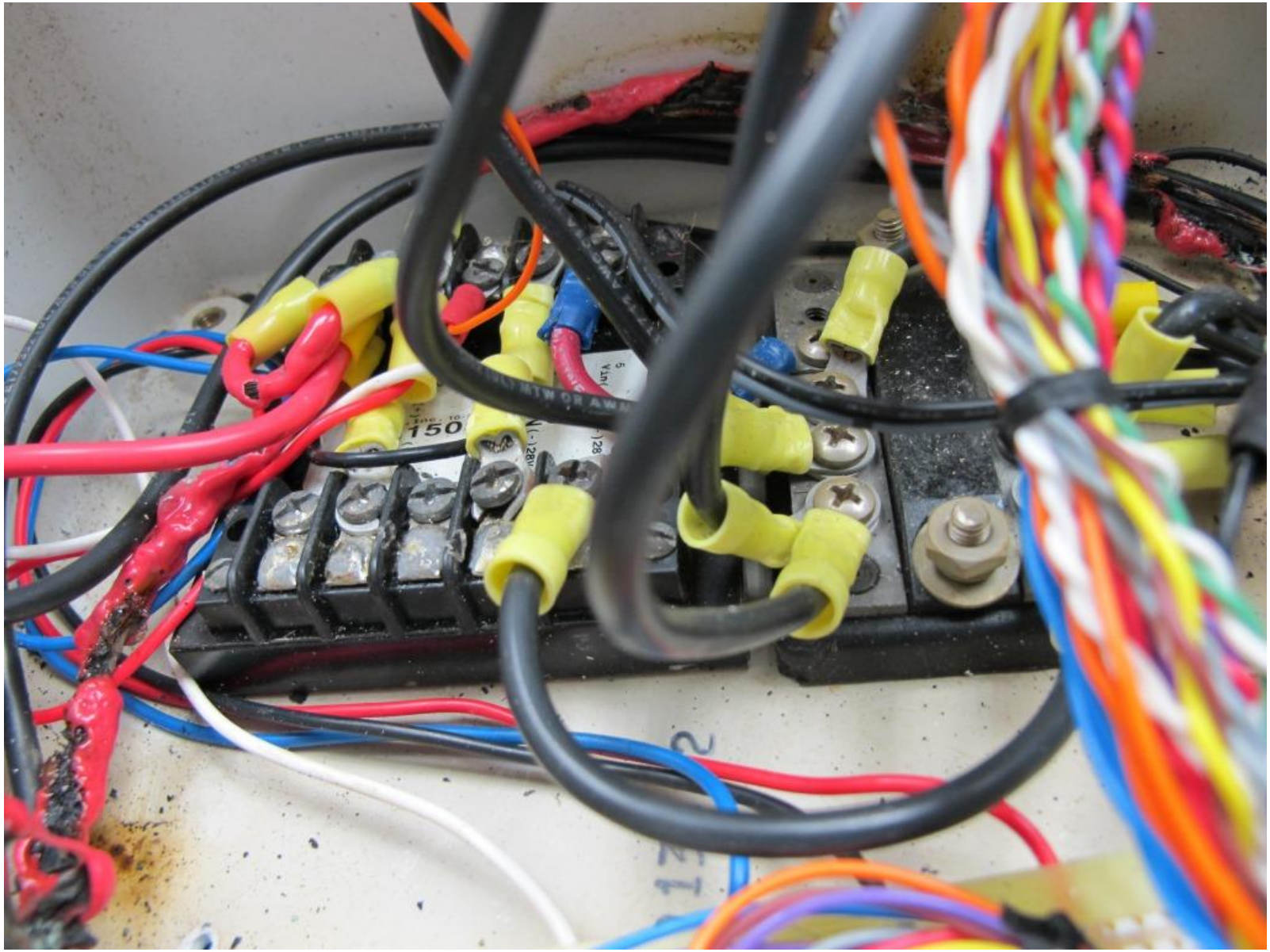


Figure 14 - Closeup of Step Up Transformer

Figure 15 - Step Up Solid State Transformer

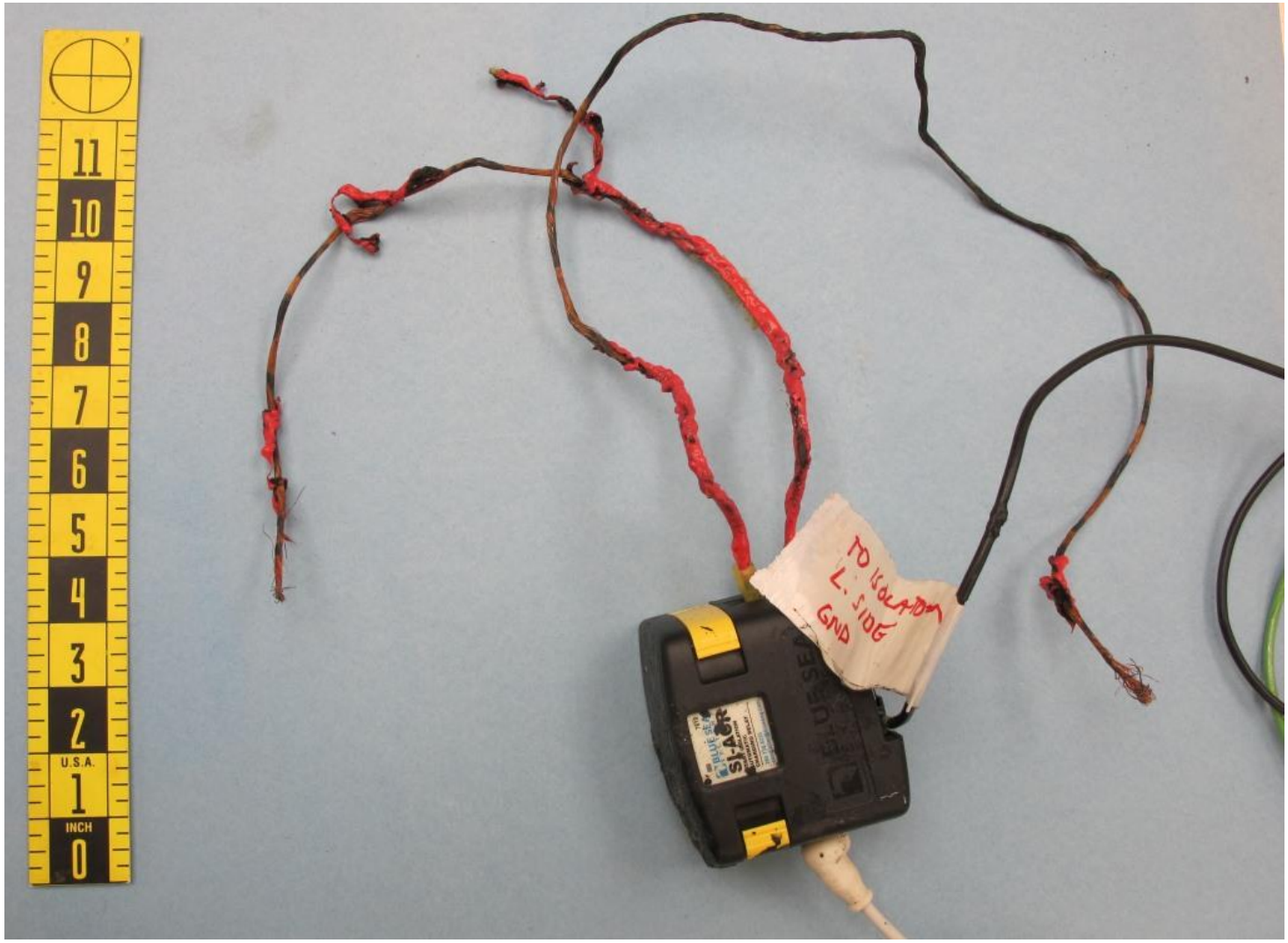


Figure 16 - Isolator Relay Box

Figure 17 - Inverter

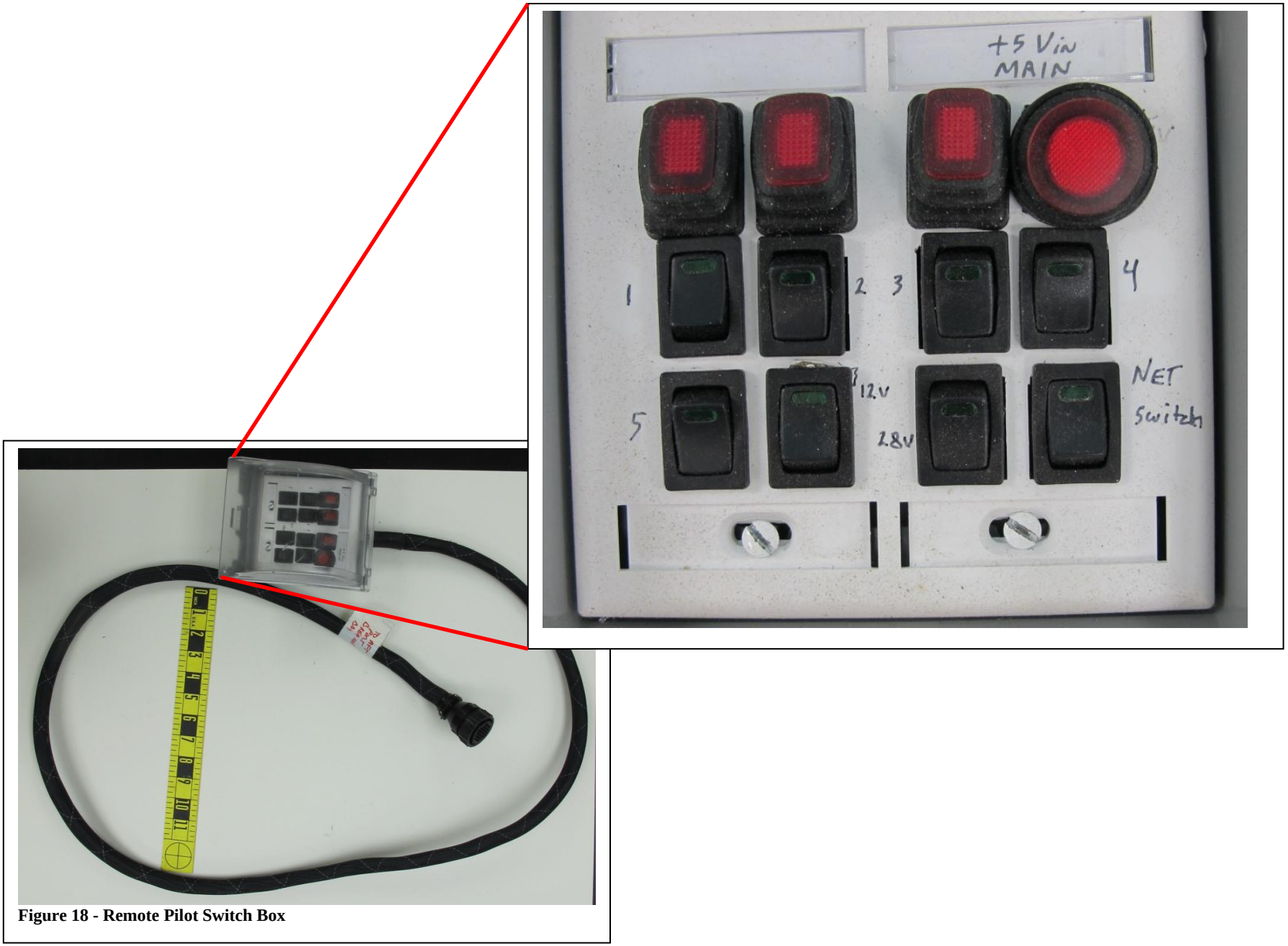


Figure 18 - Remote Pilot Switch Box

E. EXAMINATION DETAILS

1.0 Component Exam/Test Synopsis

ID for Exam Purposes	Component Name	Examination and Test Results
B	Battery Box	Thermal damage documented. Relative position, based on sooting patterns, of this and 'C' documented
C	Power distribution box;	Relative position, based on sooting patterns, of this and 'B' documented. It was noted that the grommeted hole in the bottom of 'C" which were for entry of the positive lead from switch 'D' and the negative lead from battery 'A' into this unit was situated directly above the flat surface of 'B', which meant that those two leads were captive between and directly in contact with both 'B' and 'C'
		The inner panel was unscrewed and lifted out to reveal the internal components and wiring. Most of the red 12VDC wires had their insulation melted away. The only one that did not was the lead from C-1 to the "aft left" cannon plug fitting.
C-1	Step up transformer	Removed and function-checked OK. Per design dwg, terminals 1-2 were internally linked, but tested intermittent.
C-2	Negative Buss Bar	Not Tested. Visually intact, all connections secure
C-3	Relay breadboard	Verified wiring pin connections per design dwg
D	Red Switch	Not damaged. Opened prior to rotating switch, no internal damage or arcing observed. Re-assembled and tested continuity for 3 switch positions (OFF, ON, COMBINE) Function checked OK. See test matrix below
E	Isolator; Relay	Not tested. Visually undamaged.
F	Remote Switch Box	Not tested. Appeared undamaged, as did wires to this device.
G	Circuit Breaker Panel	Impact damage but no thermal damage. 40A breaker toggle switch fracture-separated. Other breaker rating not determined, and breaker 'button' fell out of breaker housing. Neither unit tested, but as-found wiring congruent with design dwg.
H	DC-AC inverter	Red lead from "forward left" cannon plug port of 'C' to this unit was thermally damaged. Unit opened; minor impact damage but no thermal damage noted, Function checked OK
I	Wireless modem	Not tested. Minor thermal damage only

2.0 Red Switch ('D') Continuity Test

The four terminals on the underside of the red switch were numbered 1 - 4 as shown in Figure 10. Terminal 1 was wired to the isolator (E), and Terminal 2 was wired to the power distribution box (C). Terminals 3 and 4 were unused. Continuity checks via ohmmeter between the four terminals were conducted for the switch in each of its 3 positions (OFF, ON, COMBINE). Those results were as follows:

Switch OFF

	1	2	3	4
1		No	No	No
2			No	No
3				No
4				

Switch ON

	1	2	3	4
1		Yes	No	No
2			No	No
3				Yes
4				

Switch COMBINE

	1	2	3	4
1		Yes	Yes	Yes
2			Yes	Yes
3				Yes
4				

3.0 Wire Information

Several wires exhibited severe or complete melting of their insulation; the large majority of these were the red-insulated wires. Some of these wires were external to the power distribution box ('C'), some were internal, and two ran from outside to inside the box. The wires were arbitrarily identified with letters and numbers to enable cataloging, with 'R', 'B' and 'G' denoting the color of the insulation (R=red, B=black, G=green)

WIRE ID	FROM	TO	GAGE and DESIGN VOLTAGE	CONDITION/REMARKS
R1	Switch D terminal 2	Power distribution box C (bottom grommeted hole)	12-14g 12VDC	Severely melted insulation. Wire found separated in mid-run. Looked at ends of wires near fire and at mechanical failure point of wires and found a lack of evidence of arcing. Optical and scanning electron microscopes both found insufficient evidence to suggest arcing or heating as a mechanism for severance of wires. Evidence more supports separation of wire was purely mechanical and not aided by arcing. Suspect wires became disconnected due to impact of aircraft with the ground. Carbon burns from wire ends were cleaned by soaking in acetone bath in prep for ultrasonic cleaning and re-examination to search for evidence of arcing from electrical shorting. About 3 strands showed arcing globules at their failure points.
R2	Isolator E	Switch D Terminal 1	12-14g 12VDC	Severely melted insulation. Wire found separated in mid-run.
R3	House battery A (+)	Isolator E	12-14g 12VDC	Severely melted insulation. Wire found separated in mid-run.
R5	Step up transformer C (pin 1)	Box C forward left cannon plug port	12-14g 12VDC	Insulation melted. Internal to box C
R6	Step up transformer C (pin 1)	Box C aft left cannon plug port	12-14g 12VDC	Undamaged. Excised from box C and sent to FAA for Cessna lab melting point test

WIRE ID	FROM	TO	GAGE and DESIGN VOLTAGE	CONDITION/REMARKS
B1	House battery (-)	Power distribution box C negative buss bar (through bottom grommeted hole)	12-14g 12VDC	Severely melted insulation. Wire found separated in mid-run. Looked at ends of wires near fire and at mechanical failure point of wires and found a lack of evidence of arcing. Optical and scanning electron microscopes both found insufficient evidence to suggest arcing or heating as a mechanism for severance of wires. Evidence more supports separation of wire was purely mechanical and not aided by arcing. Suspect wires became disconnected due to impact of aircraft with the ground. Carbon burns from wire ends were cleaned by soaking in acetone bath in prep for ultrasonic cleaning and re-examination to search for evidence of arcing from electrical shorting. No globules consistent with arcing were observed
B2	Isolator E	Airplane chassis ground	12-14g 12VDC	Undamaged
B3	NOT USED/DESIGNATED			
B5	Buss Bar C-2	Box C forward left cannon plug port	12-14g 12VDC	Undamaged
B6	Buss Bar C-2	Box C aft left cannon plug port	12-14g 12VDC	Undamaged. Excised from box and sent to FAA for Cessna lab melting point test
R4/B4	Power distribution box C forward left cannon plug port	Inverter H (positive and negative input terminals)	12-14g 12VDC	Two wires bundled in single shroud. Pulled out of 'C 'port during accident. R4 insulator melted at both ends, B4 insulator intact/unmelted. Shroud cut away in mid-run by investigators; red insulation appeared melted.
R7 & B7	Jumpers inside C		12-14g 12 or 28VDC	Undamaged. Both 105 degree C rated with PVC insulation. Excised and validated material is PVC using IR FFT technical analysis in effort to determine why red had melted and black had not. Prompted decision to conduct melting point tests.
G1	House battery (-)	Airplane chassis ground	12-14g 12VDC	Thermally undamaged but 1 pinch (possibly due to impact)