

# National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



ENG25NA009

## **MATERIALS LABORATORY**

Factual Report 25-009

February 13, 2025

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## **A. ACCIDENT INFORMATION**

Location: Dulles, Virginia  
Date: November 19, 2024  
Vehicle: Bombardier CL-600-2C11, N501GJ  
Investigator: Adam Huray, AS-40

## **B. COMPONENTS EXAMINED**

Elevator control cable assembly, fractured in two; P/N: BA670-93710-**13**.

Elevator control cable assembly; P/N: BA670-93710-**17**.

Elevator control cable assembly; P/N: BA670-93710-**19**.

Piece of fractured elevator control cable assembly from sister aircraft N502GJ, P/N: BA670-93710-**19**.

## **C. EXAMINATION PARTICIPANTS**

Specialist Donald Kramer, Ph.D.  
National Transportation Safety Board  
Washington, DC

## **D. DETAILS OF THE EXAMINATION**

Autopilot elevator control cable assemblies from the incident aircraft were submitted to the NTSB Materials Laboratory for examination (figures 1a and 1b). A piece of fractured control cable from sister aircraft N502GJ was also submitted for examination (figure 2). One of the cables from the subject aircraft was fractured approximately 14 inches from the end that connected to the autopilot servo mount. The cable from sister aircraft N502GJ was fractured approximately 14-3/4 inches from the same end.

By design, aircraft of the above-indicated type are equipped with two autopilot elevator control cable assemblies. The cable assemblies connect to an autopilot servo mount at their input end and to a quadrant at their output end. Linear movements of the cables induce rotations of the quadrant about a pivot which in turn connects to and controls elevator pitch. One cable, referred to as the “-13” assembly, is a single cable, connecting to the autopilot servo mount at its input end and to the quadrant at its output end (figure 1a). Two other cables combine to form an assembly (figure 1b). These are the “-19” cable that connects to the autopilot servo mount and the “-17” cable that connects to the quadrant. These two cables connect to one another via a turnbuckle (not shown). The turnbuckle allows the cable tension in the control assembly to be adjusted.

This report covers the laboratory examination of the fractured cable from the incident aircraft, the examination of the fractured cable from the sister aircraft, observations of wear and wire fractures from examination of the remaining cable assembly pieces, and chemical analysis of the cables.

## **1.0 Fracture of incident aircraft cable assembly**

The fractured cable from the incident aircraft was a "-13" cable that connected to both the servo mount and the quadrant. The cable had fractured approximately 14 inches from the servo mount end. Near the fracture, regions of the cable exhibited a rust-colored tint, and only a few strands/wires exhibited deformation bending or splaying (figures 3a and 3b). Closer examination of the fractured cable ends indicated that most of the wires exhibited flat fracture surfaces. The majority of individual wires were worn within the rust-tinted region and, in particular, worn adjacent to the wire fractures (figures 4a and 4b).

The wire fractures exhibited features consistent with cyclic fatigue. The fatigue cracking initiated near the edge of worn regions, progressing along the transverse direction through the wires. The fractured cable end on the output (quadrant) side of the fracture was cut in the laboratory from the rest of the cable, and the strands were separated (seven strands total, seven wires per strand, i.e., a 7x7 cable). Several strands that exhibited predominantly flat fractures were examined using a scanning electron microscope (SEM) (for example, figures 5a and 5b). The flat fracture regions were covered in debris and exhibited pitting and rubbing damage. One side of the wire had fractured on a slant plane, consistent with a region of final overstress fracture. On the opposite side of the wire, the edge of the flat wear region met the original outer diameter surface of the wire.

The other strands were examined to find one with less damage to the wire fracture surfaces. One strand displayed flat fracture regions that comprised approximately 25 % of the fracture surface or less. These fractures exhibited less post-fracture damage. A wire from that strand is shown in figures 6a - c after a 5-minute soak in a chelating rust removal solution. The fracture surface exhibited a thumbnail-shaped region with a silver-metallic appearance, consistent with progressive fracture. Closer examination of the thumbnail region by SEM revealed curved crack arrest marks and a fine feathery appearance, consistent with cyclic fatigue. The fracture originated near the edge of a wear region on the outer surface of the wire.

## **2.0 Fracture of sister aircraft cable assembly**

The fractured cable fragment from sister aircraft N502GJ was from a "-19" cable (figure 2). The "-19" cable assembly connected to the servo mount at one end and terminated at a threaded turnbuckle fitting at the other. The cable was fractured approximately 14-3/4 inches from the servo end. Near the fracture, regions of the cable exhibited a rust-colored tint and only a few strands/wires exhibited deformation

bending or splaying (figure 7a). Closer examination of the fractured cable ends indicated that most of the wires had flat fracture surfaces and that the individual wires exhibited wear adjacent to the fracture surfaces and the adjoining wire surfaces (figure 7b). The location of the fracture, wear features, and fracture features were similar to those found on the fractured cable from the incident aircraft, consistent with wear and cyclic fatigue.

### 3.0 Additional wear and wire fracture indications

The cables were examined with the aid of a stereomicroscope. Rust-colored wear indications were observed between strands at the locations indicated in table 1 below. For comparison purposes, a typical section from a "-19" cable assembly is shown in figure 8a.

**Table 1.** Tabulated wear and fracture features on all submitted cable assemblies.

| Aircraft | Cable Part No. | Location                 | Indication |
|----------|----------------|--------------------------|------------|
| 501GJ    | -13            | 14 in from servo end     | fracture   |
| 501GJ    | -19            | 14 in from servo end     | rust/wear  |
| 502GJ    | -19            | 14-3/4 in from servo end | fracture   |
| 501GJ    | -13            | 3-1/2 in from quad end   | rust/wear  |
| 501GJ    | -17            | 3-1/2 in from quad end   | rust/wear  |

The wear indications were observed on the incident aircraft "-19" cable approximately 14 inches from the servo mount end (figure 8b), "-13" cable approximately 3-1/2 inches from the quadrant end (figure 9a), and "-17" cable approximately 3-1/2 inches from the quadrant end (figure 9b). The approximate lengths of the rust/wear regions were 1.25 in, 1.1 in, and 0.8 in, respectively.

The "-19" cable outer strands were removed at the location of the rust/wear indication and the underlying wires were worn, rusted, and, in some instances, fractured. The strands were cut initially by using a handheld rotary tool with grinding disk and finished using a utility knife. First, a single strand was removed (figure 10a). The underlying wires exhibited wear and were coated by rust-colored wear debris. A wire that was part of the core strand was fractured at the location indicated in figure 10a and shown in figure 10b.

Strands were removed one at a time until all the outer helical strands were removed (figures 10c and 10d). The core strand (figure 10d) exhibited wear, was covered in rust-colored wear debris, and contained approximately 10 wire breaks over an approximately 1.25-inch length. All wires were fractured in at least one location and some wires were fractured in multiple locations. Four of the six outer helical strands contained a single fractured wire. Examples from two of those strands are shown in figures 11a and 11b. The fractured wires were worn and exhibited rust-

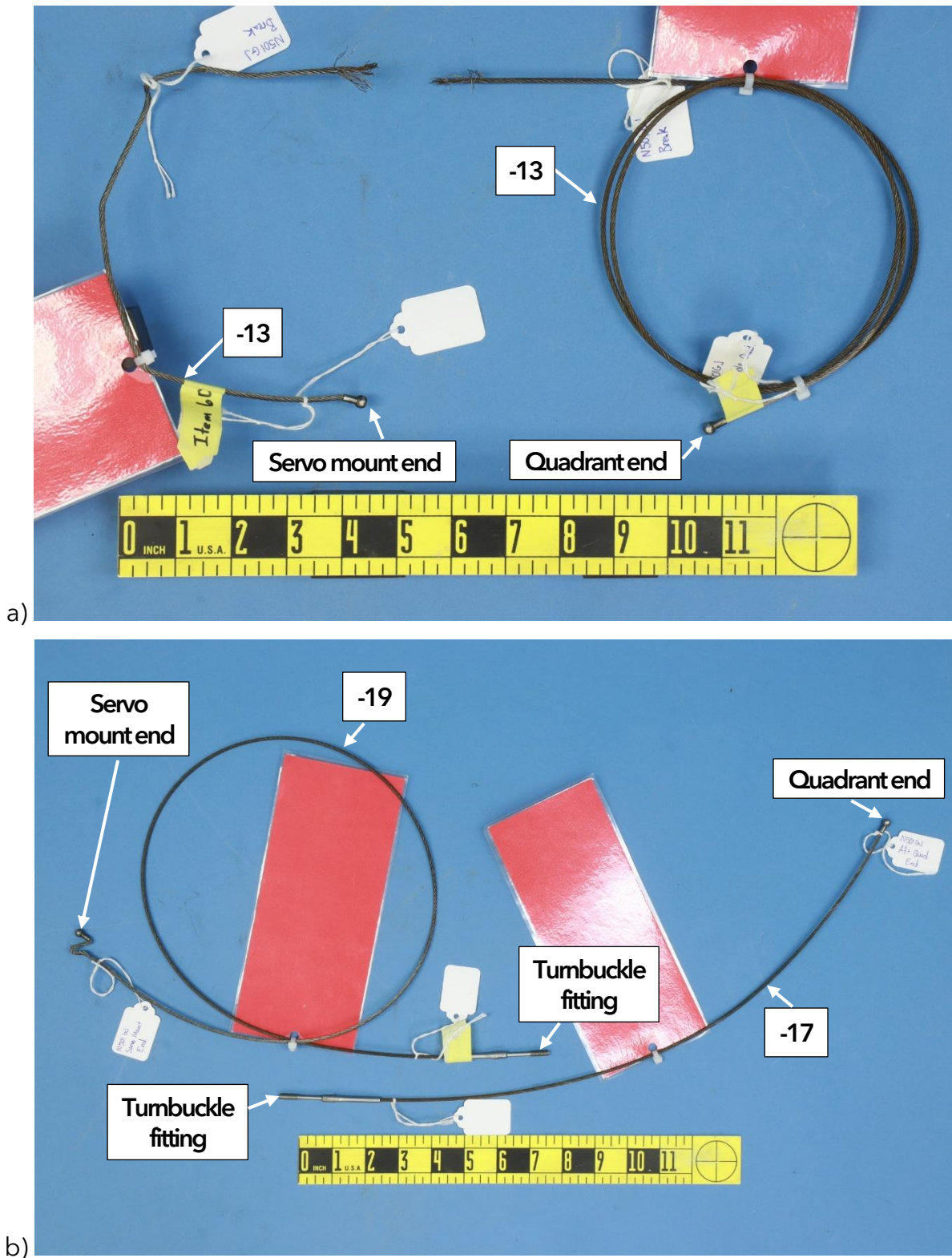
colored wear debris at the fractures, consistent with fracture occurring on the inward facing wires within the strands.

#### **4.0 Chemical analysis**

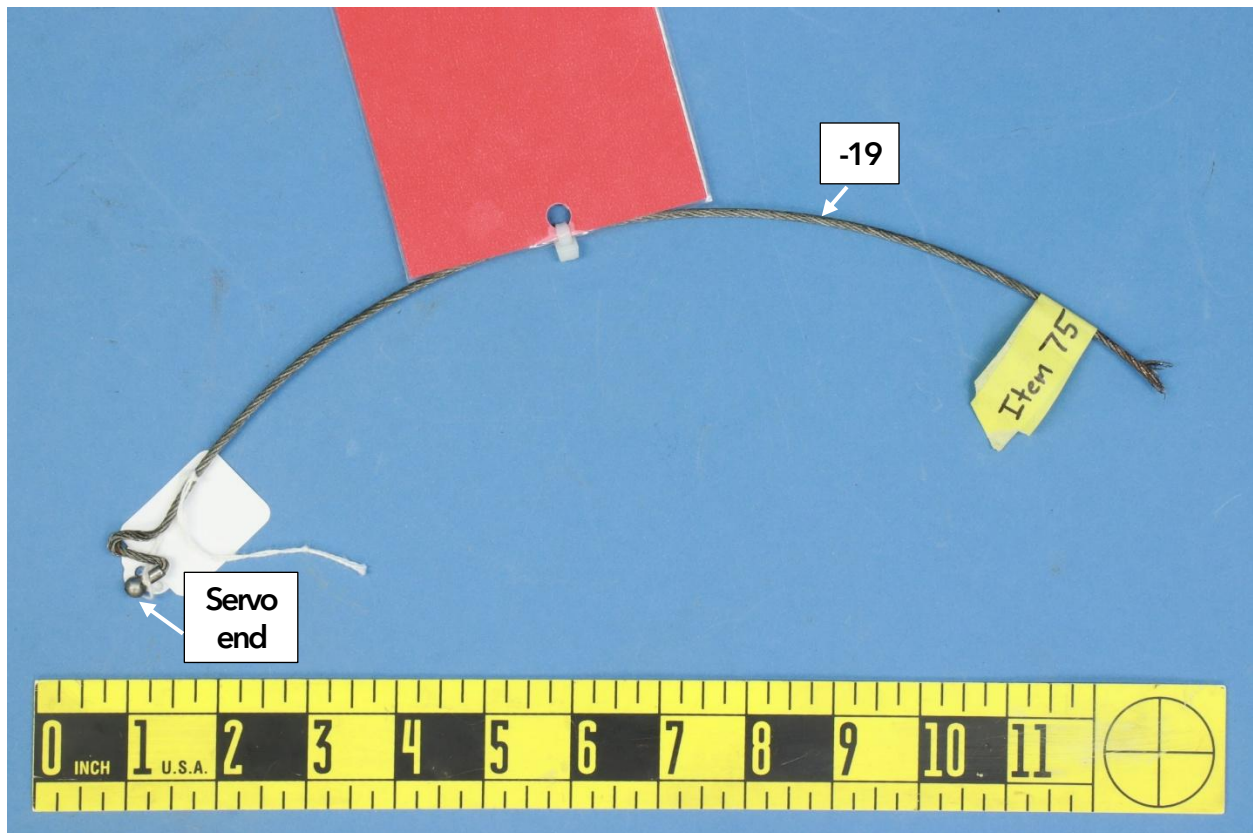
Using a handheld X-ray fluorescence spectrometer, the chemical composition of the cables was found to be consistent with the manufacturer's specifications. The spectrometer was used to detect the abundance of elements on the surface of a cable. The top three elements were iron (Fe), zinc (Zn), and tin (Sn) followed by silicon (Si) and manganese (Mn). The results were consistent with zinc- and tin-coating of the cable's steel wires.

Submitted by:

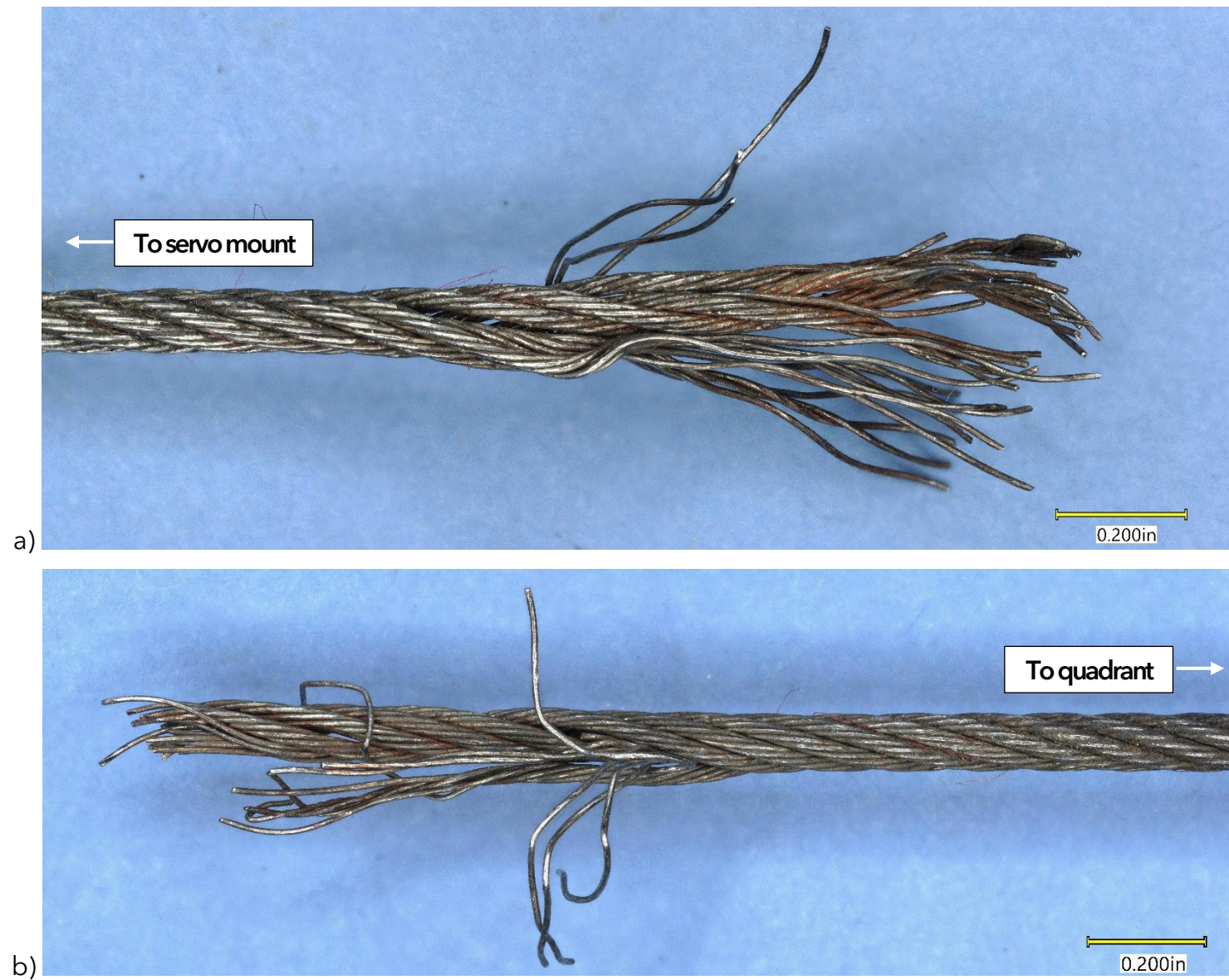
Donald Kramer, Ph.D.  
Senior Materials Engineer



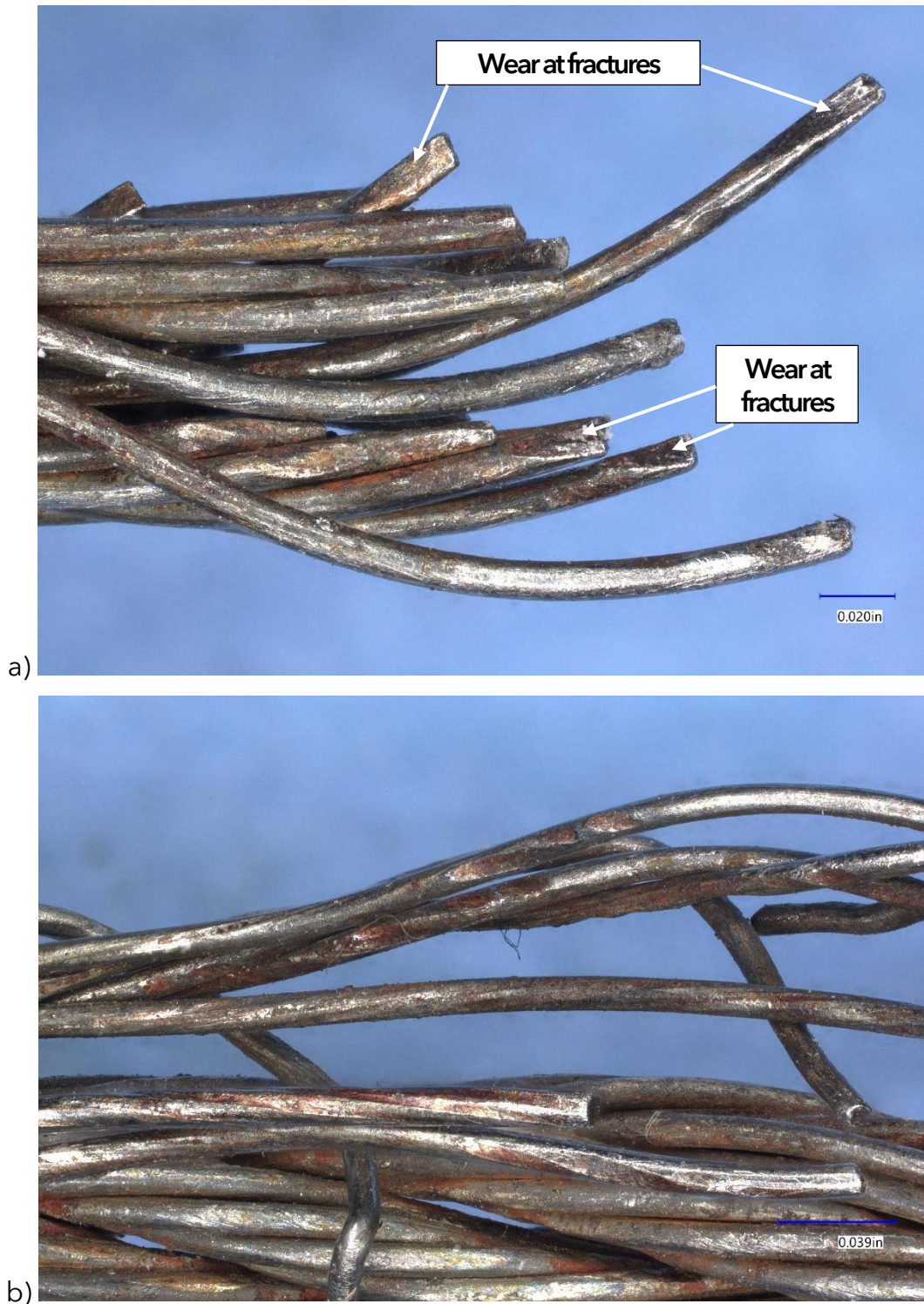
**Figure 1.** Elevator control cables from N501GJ: a) "-13" assembly, fractured and b) "-17" and "-19" assemblies absent the connecting turnbuckle.



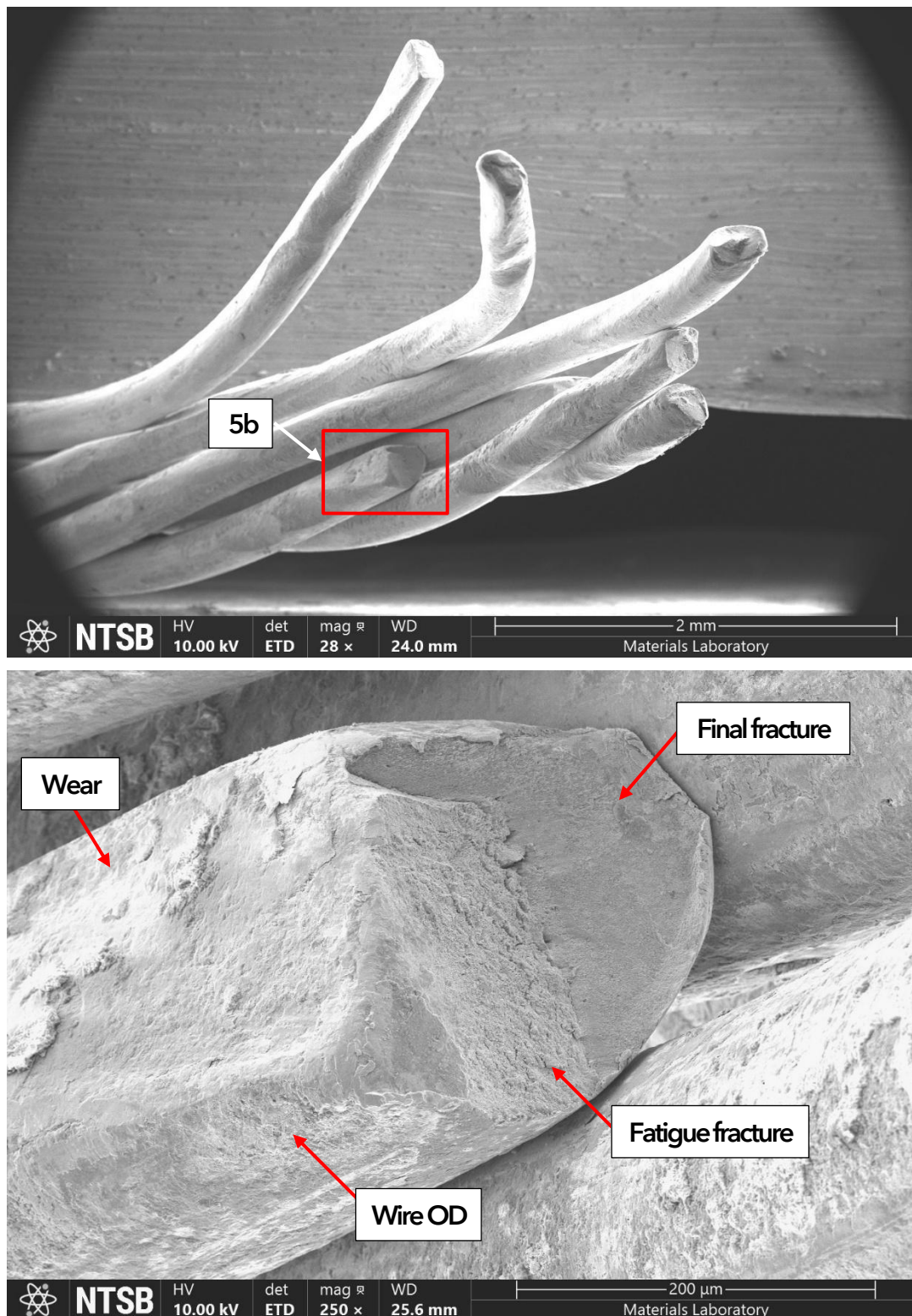
**Figure 2.** Piece of fractured "-19" elevator control cable assembly from sister aircraft N502GJ. The cable is listed as "Item 75" in the aircraft Illustrated Parts Catalog.



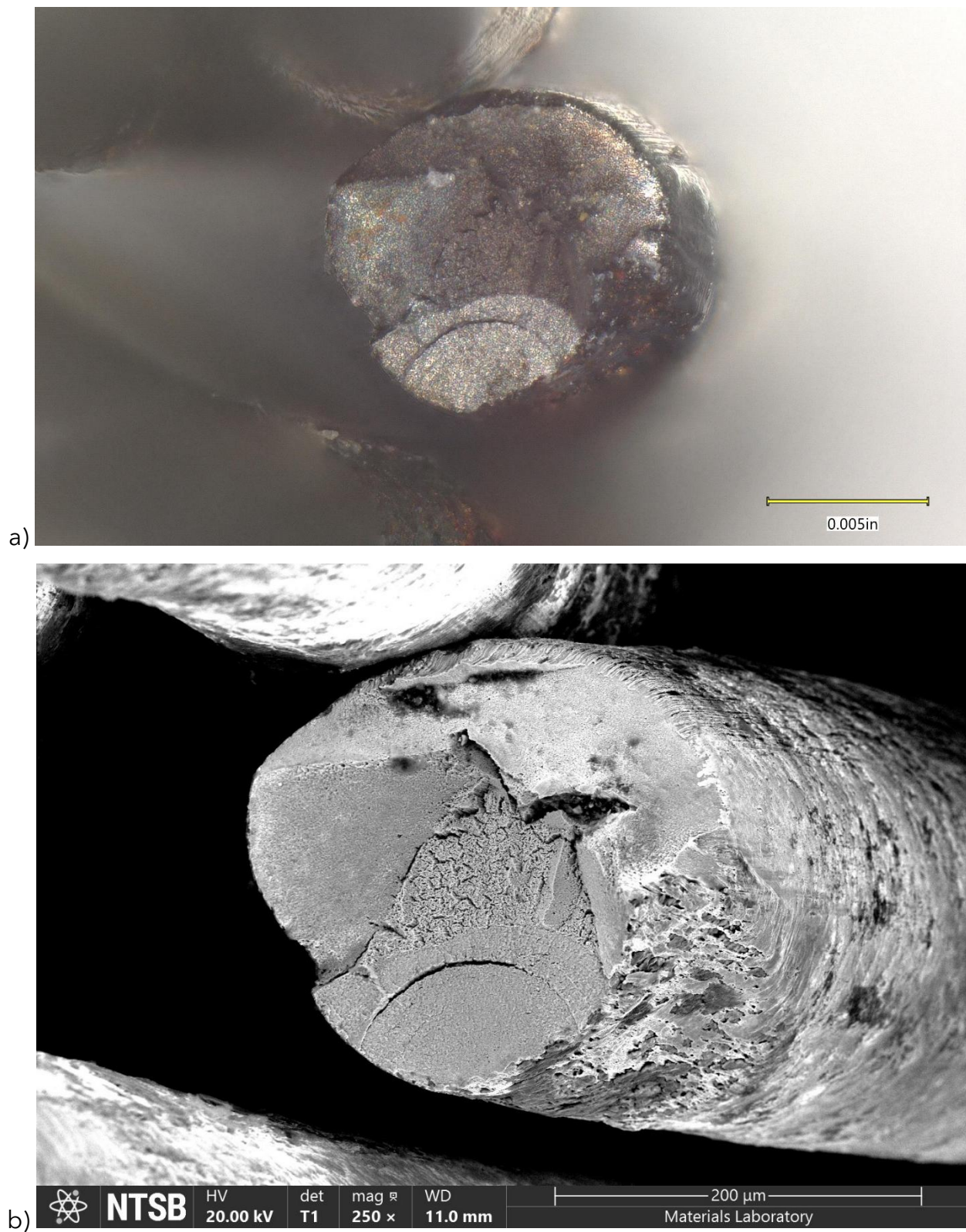
**Figure 3.** Fractured mating ends of the "-13" cable from N501GJ: a) input-side fracture and b) output-side fracture.



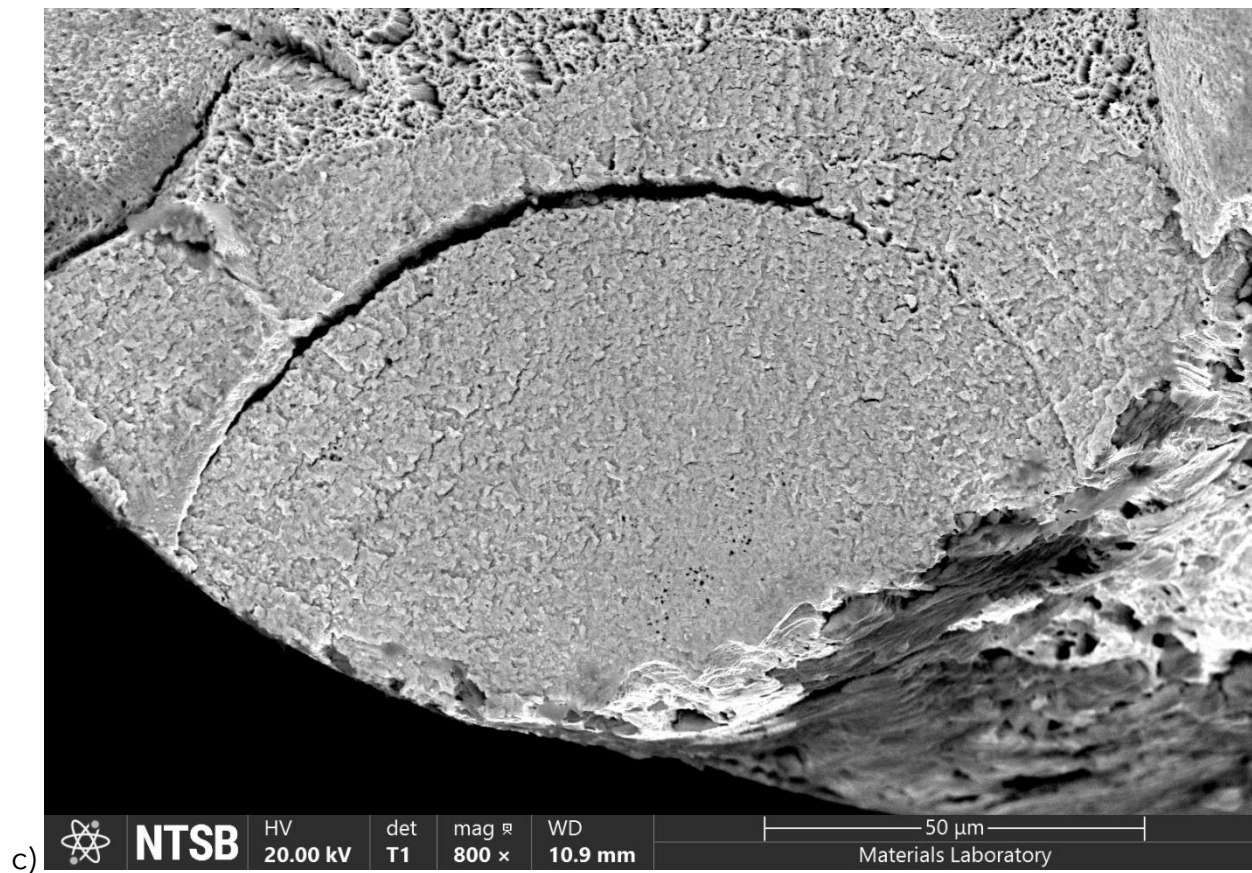
**Figure 4.** a) and b) Optical microscope images of the fractured “-13” cable showing flat-fractured wires and wear adjacent to the fractured wire ends and within the rust-tinted region.



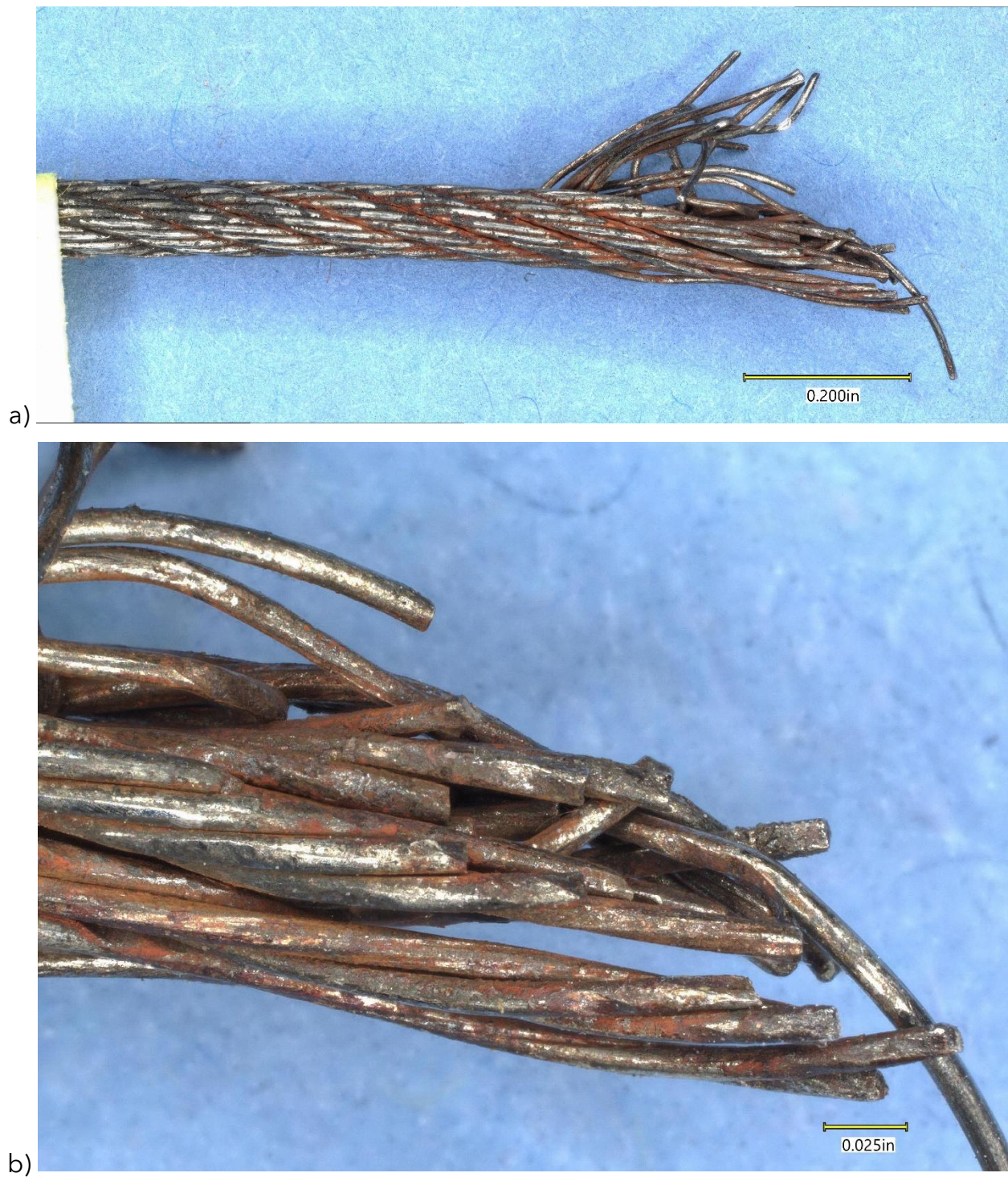
**Figure 5.** a) Low magnification scanning electron microscope image of a strand and b) higher magnification image of a wire showing the flat fatigue fracture region and the slant fracture at the point of final separation.



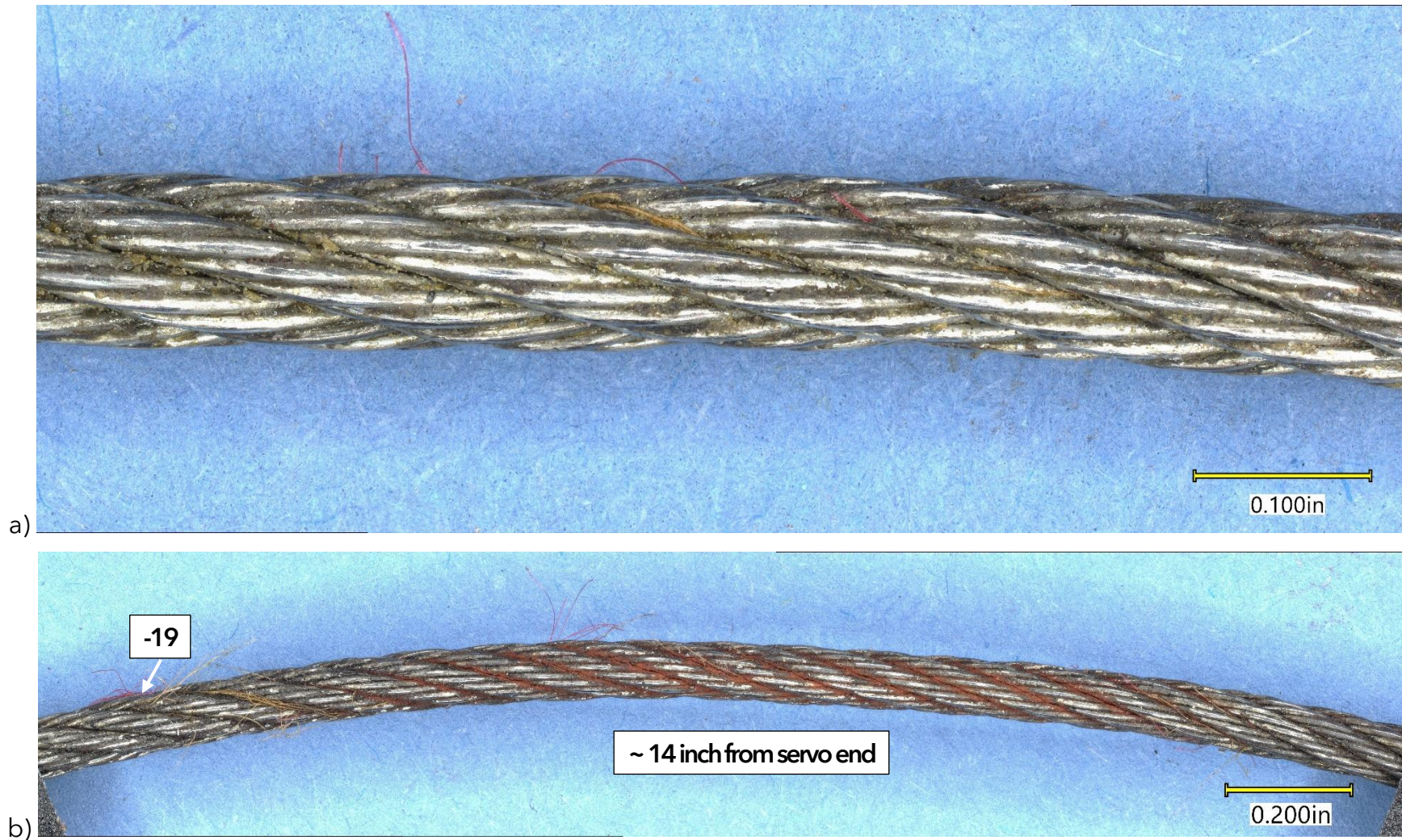
**Figure 6.** a) Optical microscope image of fracture wire with thumbnail-shaped progressive fracture region; b) scanning electron microscope image of the same wire; and



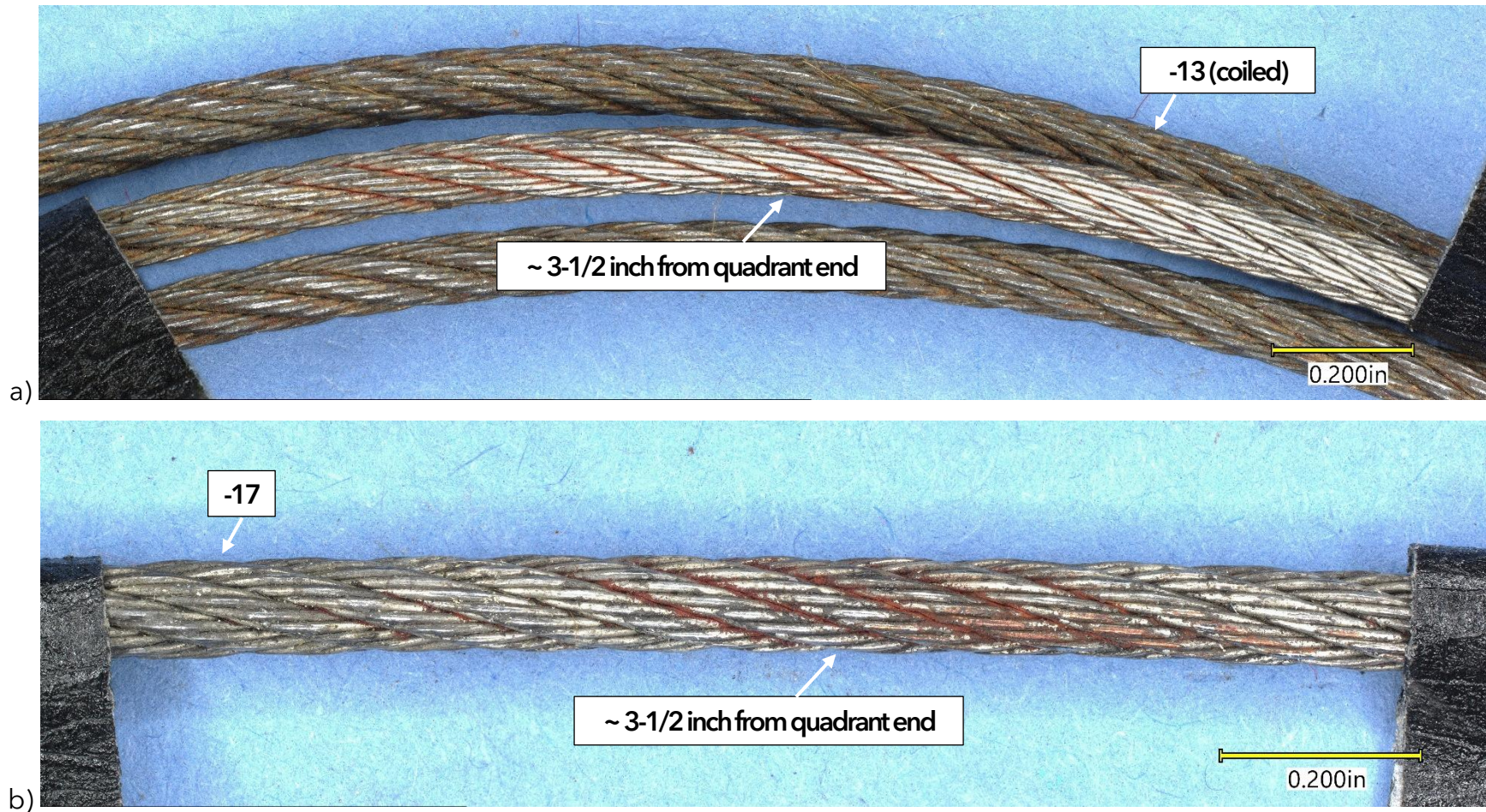
**Figure 6 (cont.).** c) higher magnification image of progressive fracture region showing crack arrest marks and feathery features, consistent with cyclic fatigue.



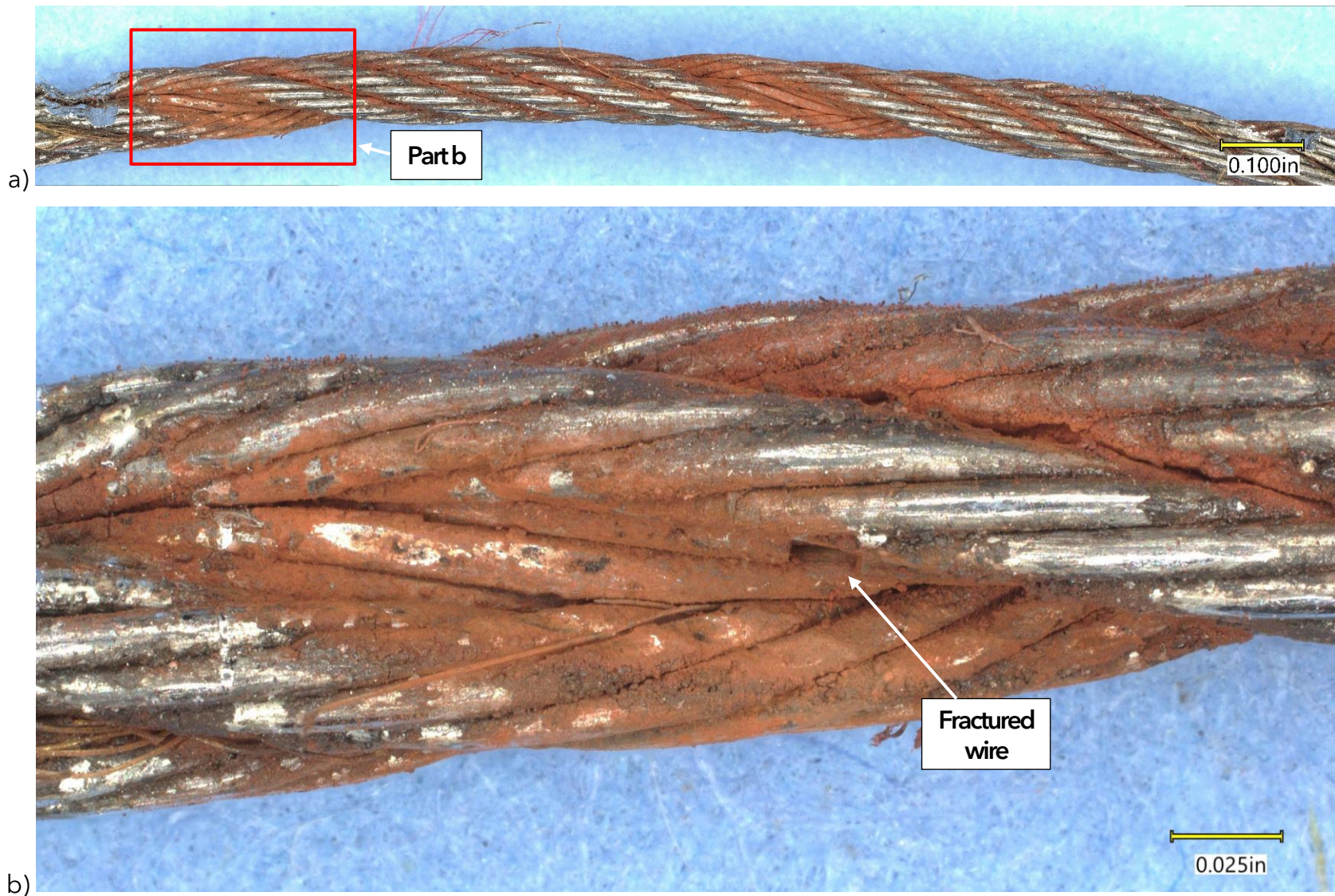
**Figure 7.** Fractured "-19" cable assembly from N502GJ: a) overview image of fractured end and b) higher magnification image showing wire wear and flat fractures.



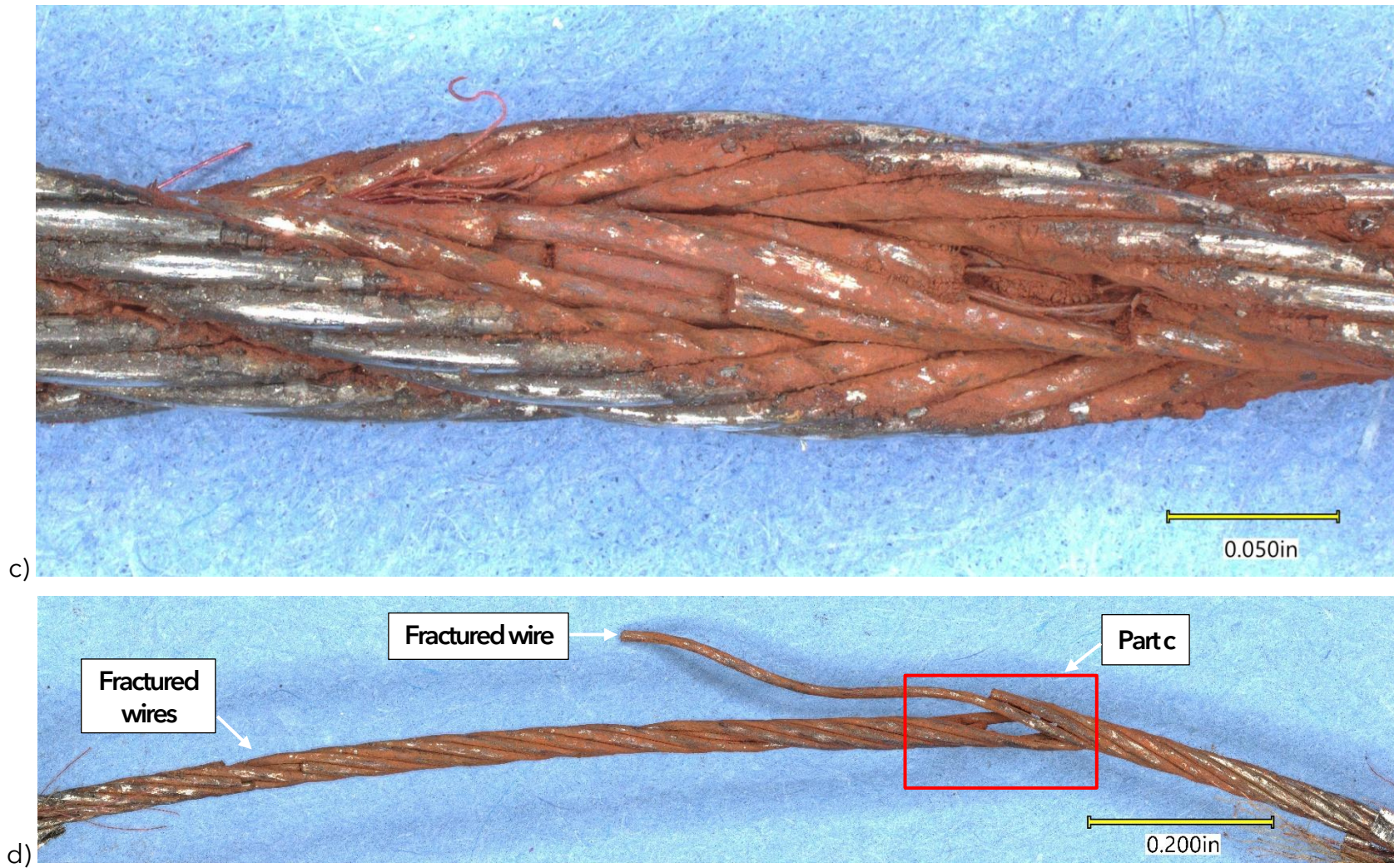
**Figure 8.** a) Image of typical cable section and b) image of rust-colored wear region, approximately 14 inches from the servo mount end on the "-19" cable from the incident aircraft.



**Figure 9.** a) Image of rust-colored wear region, approximately 3-1/2 inch from the quadrant end on the "-13" cable from the incident aircraft and b) image of rust-colored wear region, approximately 3-1/2 inch from the quadrant end on the "-17" cable from the incident aircraft.



**Figure 10.** Images of the wear region on the “-19” cable from the incident aircraft: a) overview image with one strand removed; b) close up image showing fractured wire on core strand;



**Figure 10 (cont.).** c) close-up image with two strands removed from area indicated below in part d; and d) overview image of core strand with all outer helical strands removed.



**Figure 11.** a) Lower magnification image of helical strand with fractured wire and b) higher magnification image of fractured wire on a second helical strand.