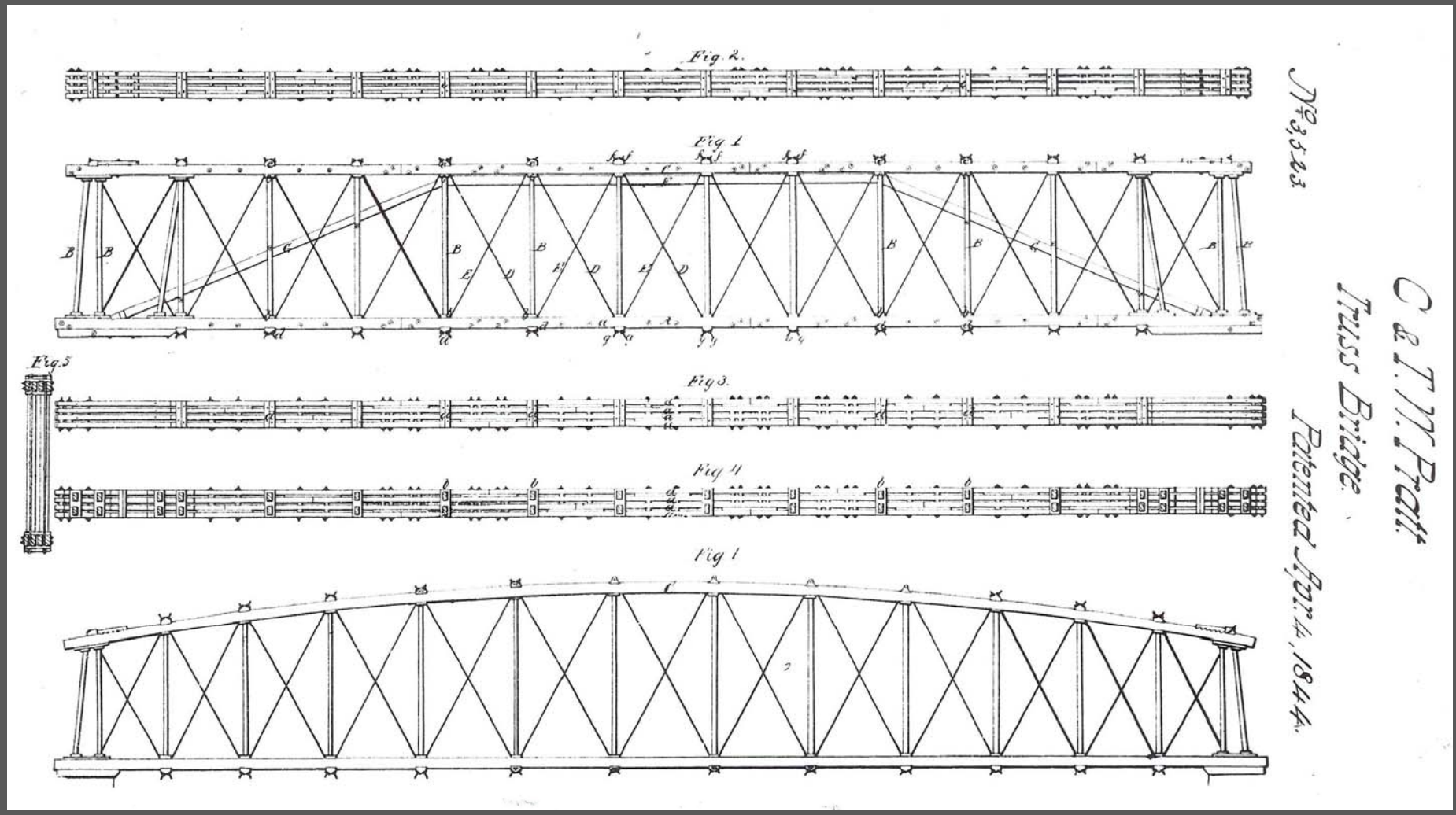
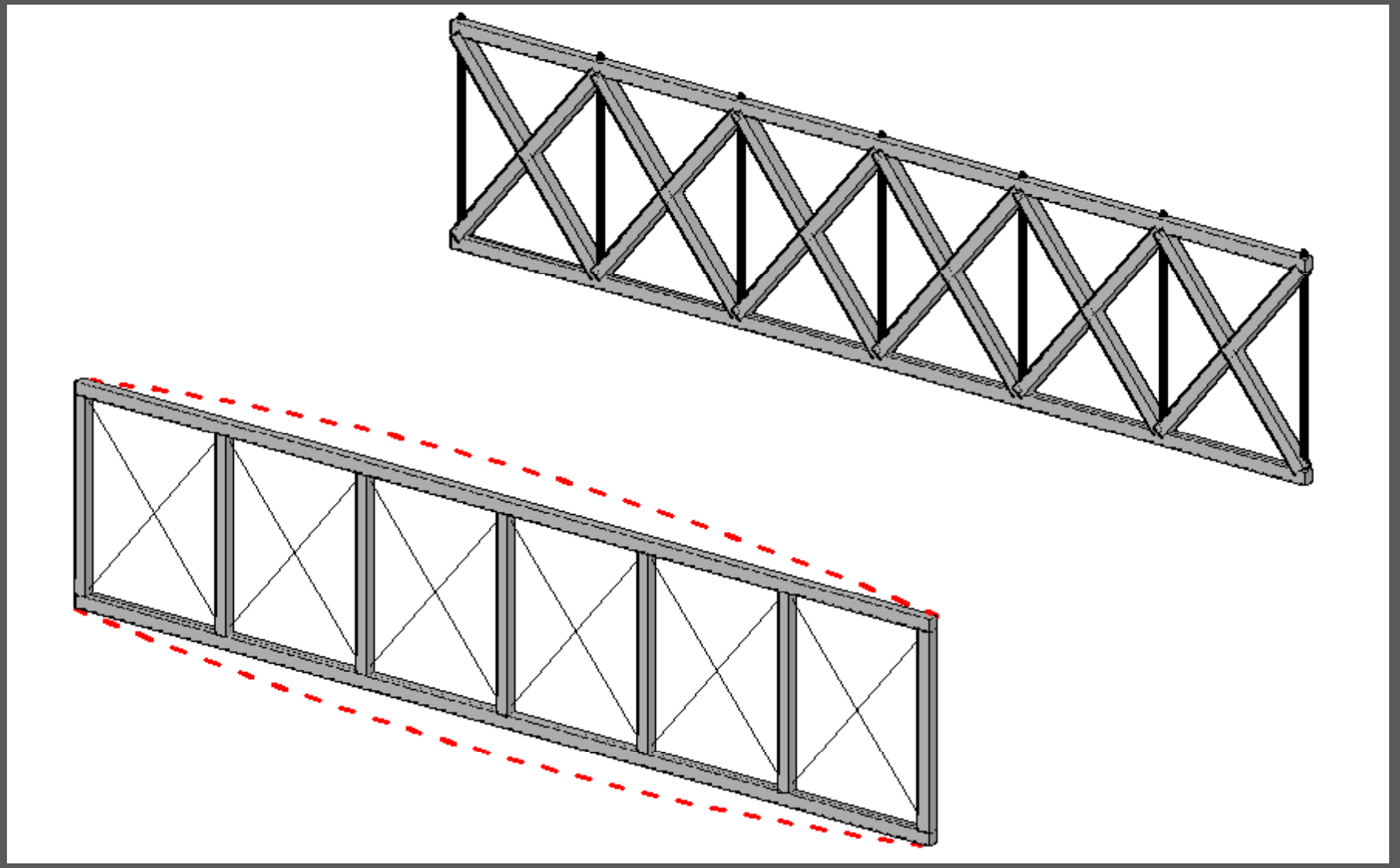
The Wright Brothers and the Pratt Truss

by

Dario Gasparini
Case Western Reserve University



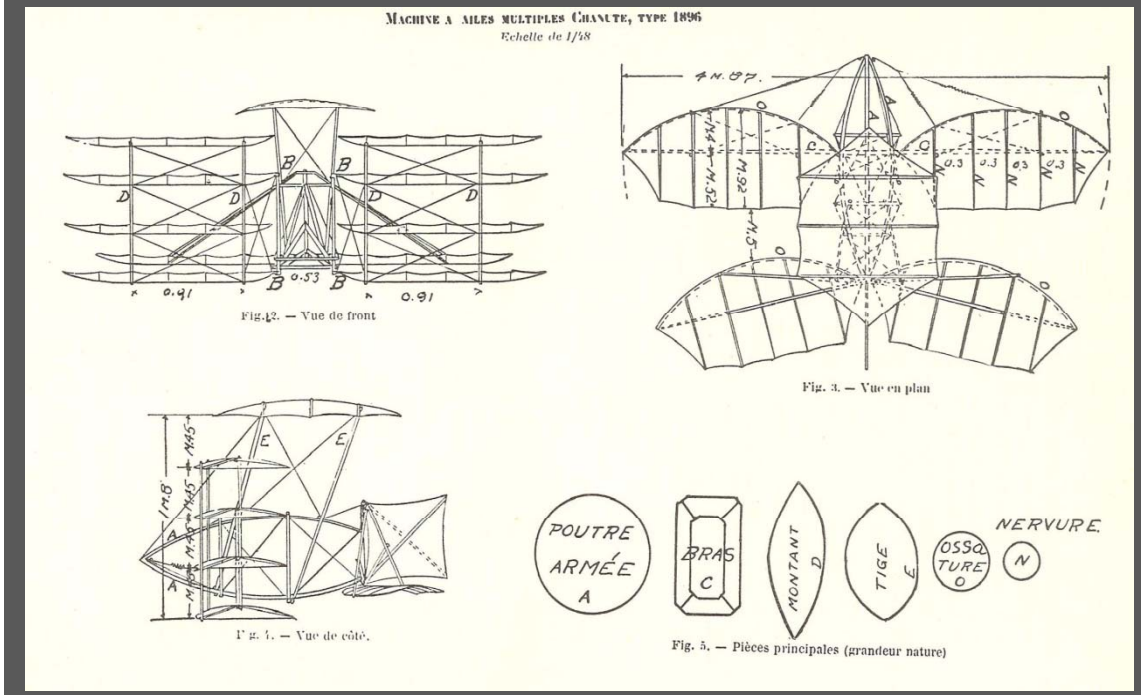
The Thomas and Caleb Pratt truss patent, April 1844
A wrought iron-diagonal version of S. H. Long's 1839 truss. Post-tensioned, with no positive connections between the verticals and the chords. Diagonals are tightened to form a stiff truss.

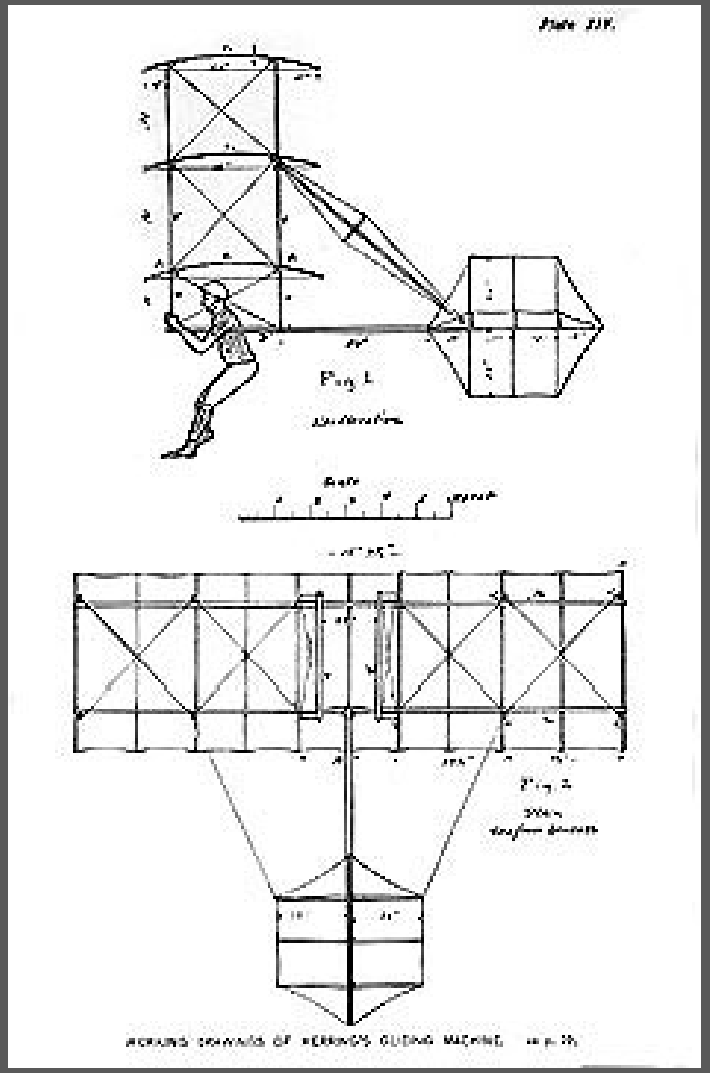


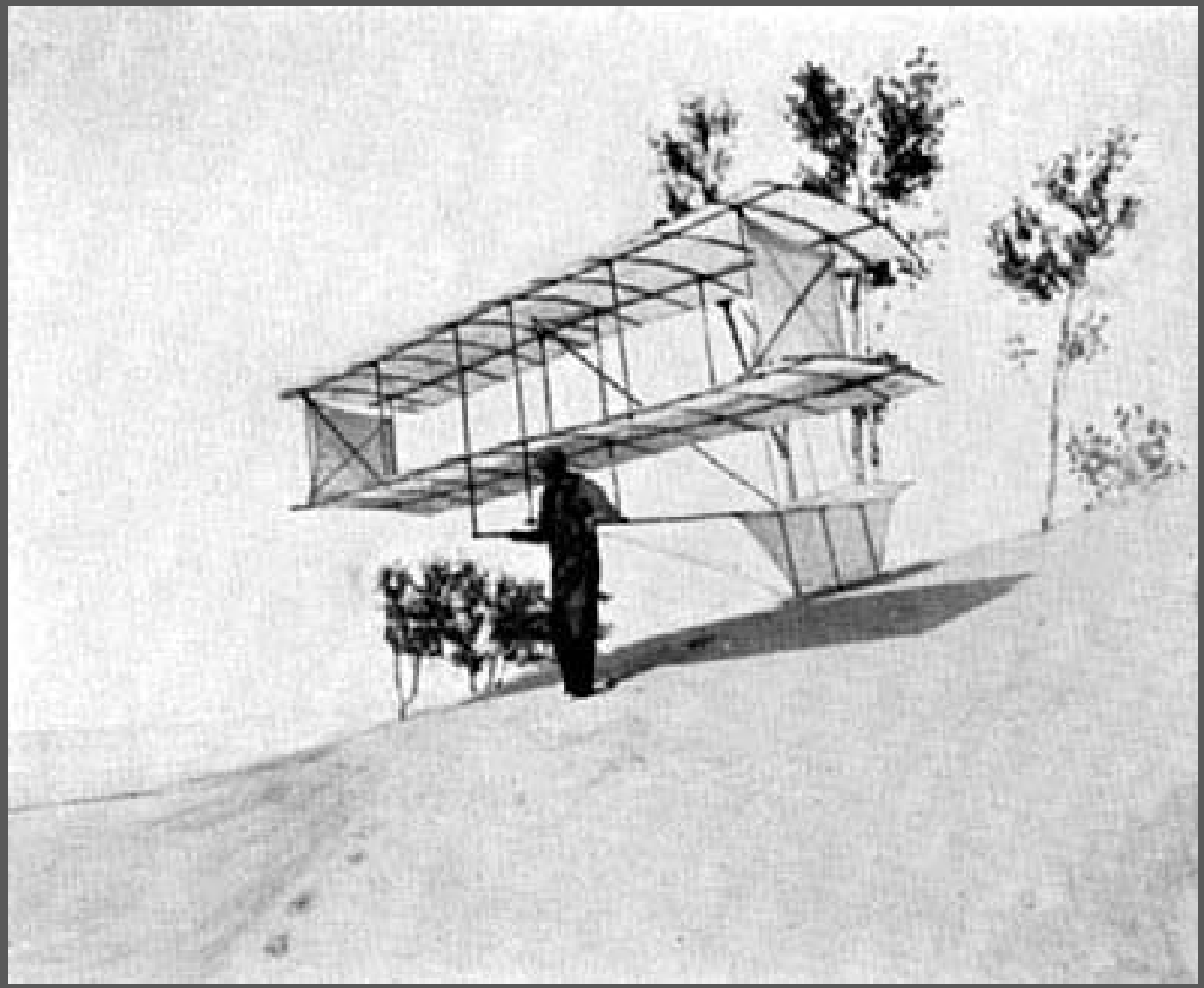
Pratt truss is “unstable out-of-plane,” whereas the Howe truss is “stable out-of-plane”

Octave Chanute (1894) “Progress in Flying Machines”
Otto Lilienthal (1889) “Der Vogelflug als Grundlage der Fliegekunst”
Hermann Moedebeck (1895) “Taschenbuch zum praktischen Gebrauch für Flügechniker und Luftschiffer”

Octave Chanute and Augustus Herring gliders of 1896 and 1897



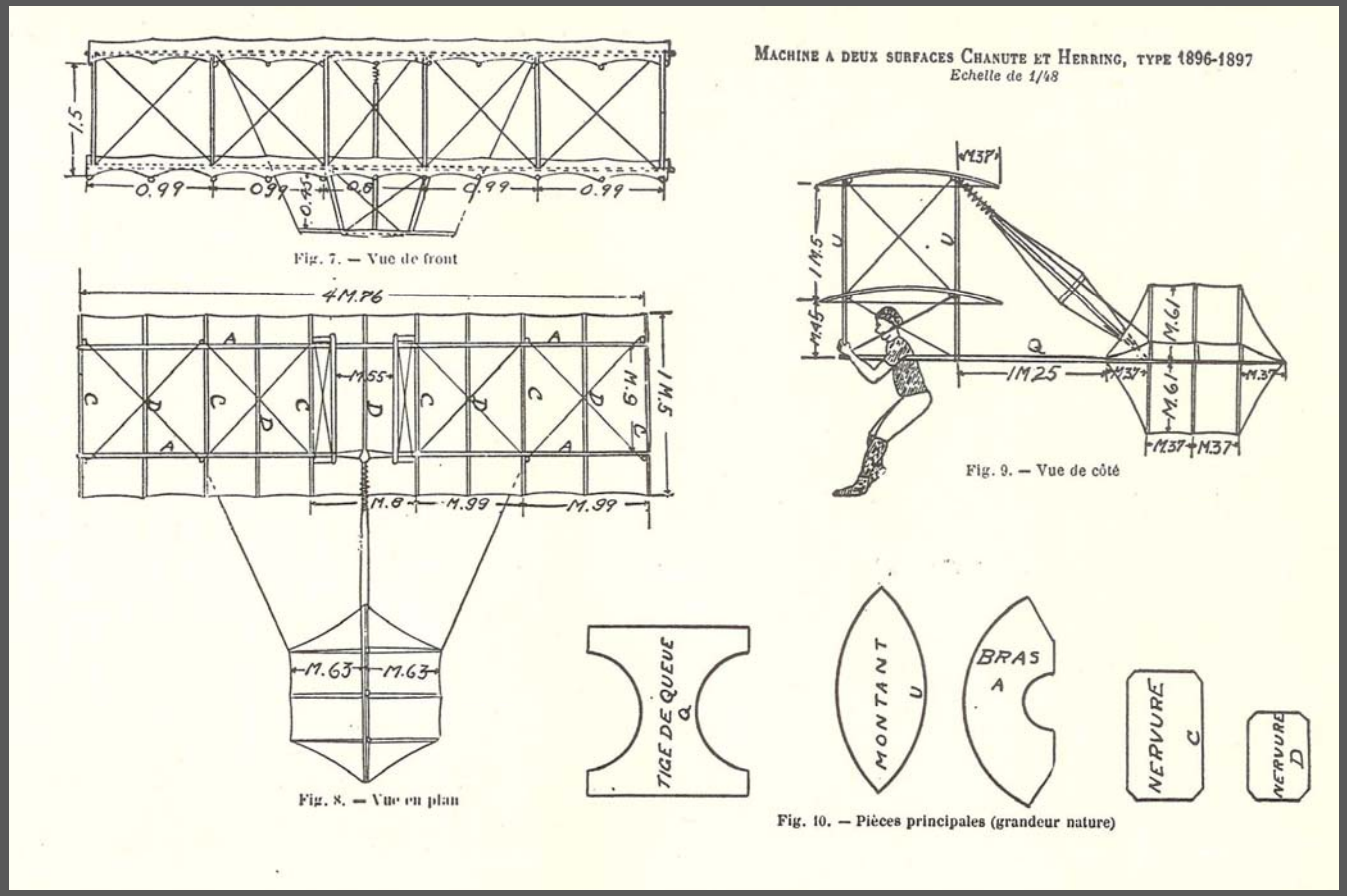




Octave Chanute and Augustus Herring glider tests of 1896 and 1897 at Dune Park, Indiana, near Lake Michigan

“Mr. Herring says he built a two-decker, instead of a three-decker machine, for Mr. Arnot because it is cheaper…… I would advise a three-plane machine rather than a double-decker…” Octave Chanute, Sept. 29, 1897

Chanute had a “three-decker” glider built and tested with the Wrights at Kitty Hawk in 1902. The results were “unsatisfactory.”



“The double-deck machine, built and tried at the same time, marked a very great structural advance, as it was the first in which *principles of the modern truss bridges* were fully applied to flying-machine construction..” “…after long study, we contrived a system consisting of two large surfaces on the Chanute double-deck plan.” - Wilbur Wright, 1901

“In the main frame a few changes were made in the details of construction and trussing employed by Mr. Chanute. The most important of these were (1) the moving of the forward main crosspiece to the extreme front edge; (2) the encasing in the cloth of all crosspieces and ribs of the surfaces; (3) a rearrangement of the wires used in trussing the two surfaces together, which rendered possible to *tighten all the wires by simply shortening two of them*.” - Wilbur Wright, 1901

We used fifteen-gauge spring steel wire. By tightening the wire *a* every other wire was tightened. The surfaces were thus left capable of torsion, and this was the method we used to maintain lateral equilibrium.

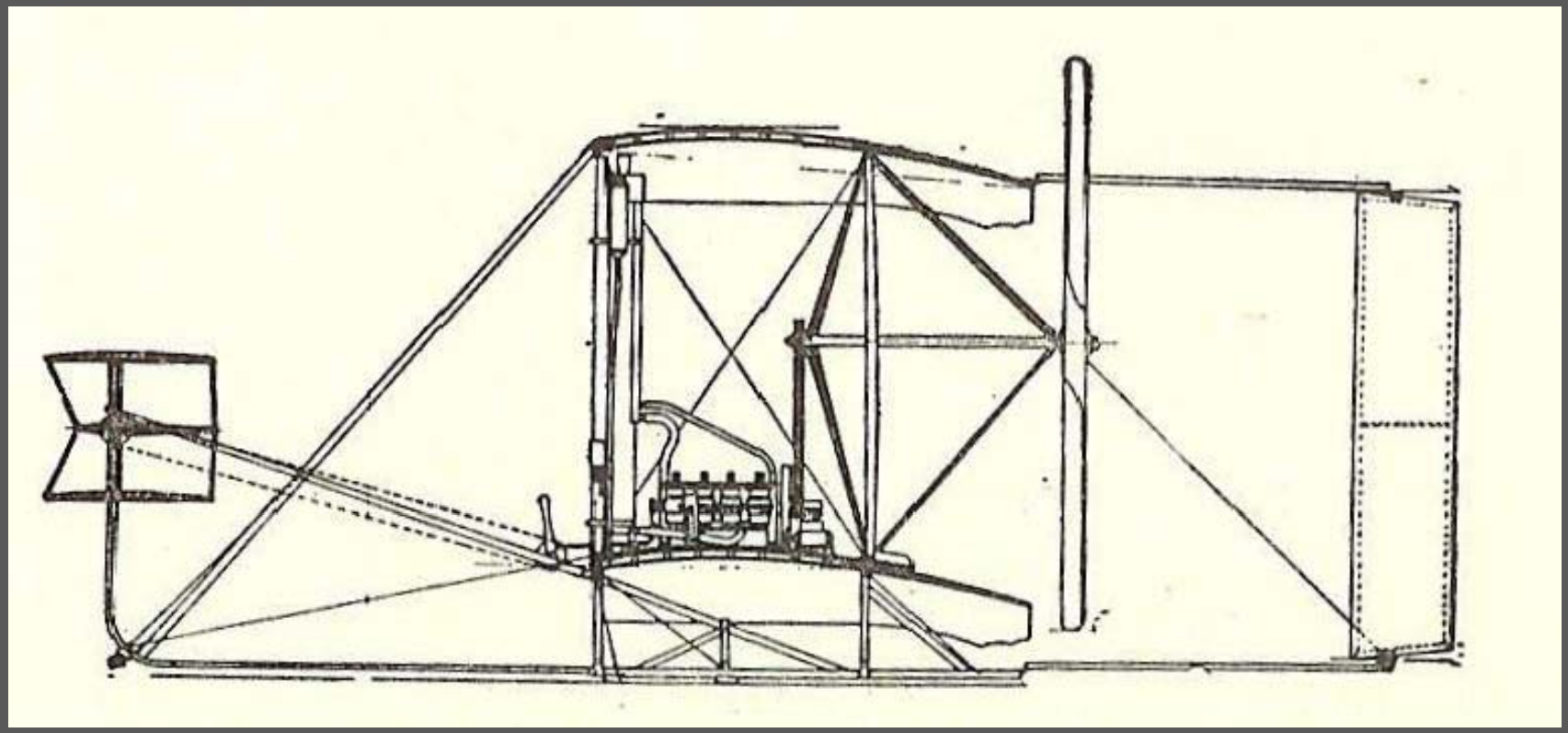
Wilbur Wright to Octave Chanute, November 16, 1900

Wrights' 1900 - 1905 designs

- **1900 Glider (17ft span, 177 ft^2)**
- **1901 Glider (22ft span, 290ft^2)**
- **1902 Glider (32ft span, 305 ft^2)**
- **1903 Powered Flyer I (40ft 4inch span, 510 ft^2)**
  (at Smithsonian, Washington, DC)
- **1904 Powered Flyer II**
- **1905 Powered Flyer III (40ft 6inch span, 503 ft^2)**
  (at Carillon Park, Dayton, OH)

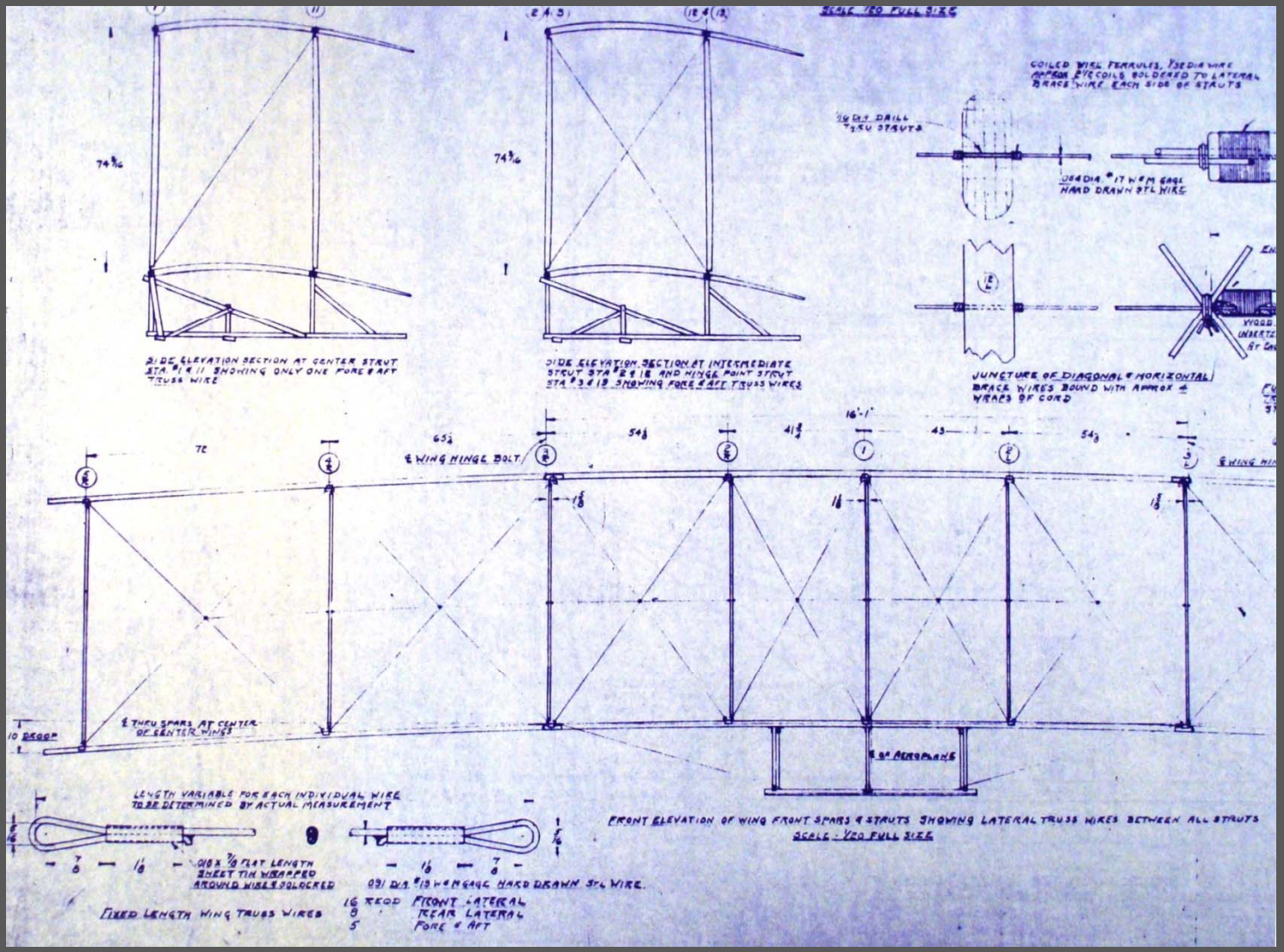
Wrights' design of the Pratt trusses

- **Scale (area of two wing surfaces) – Provide adequate lift at envisioned air speeds**
- **Geometry – "Dihedral" angle vs. "droop" ("cathedral" angle)**
  - **Depth of truss**
  - **Panel widths**
- **Materials**
  - **Wood vertical struts, wood "spars" (chords), wood ribs**
  - **Wire diagonals**
  - **Cloth cover**
- **Member sizes**
- **Joints**

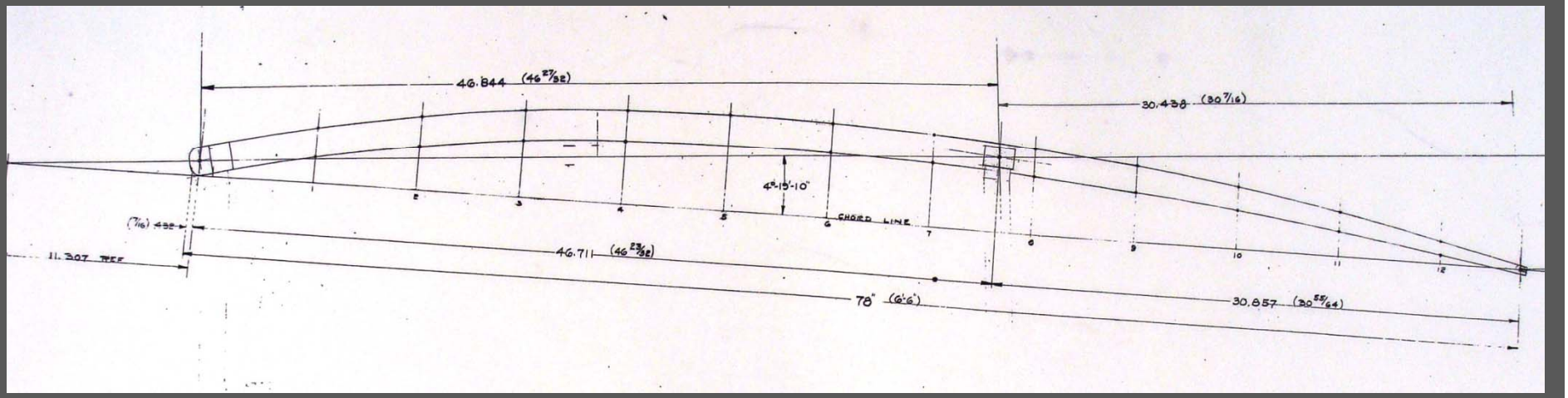


“We retained the elevator in front for many years because it absolutely prevented a nose dive such as that in which Lilienthal and many others since have met their deaths.”

Orville Wright to Alexander Klemin April 11, 1924



1903 Flyer I (as drawn in 1948) – Unequal panels, 10 inch “droop”



The 1903 Flyer I was the first to have airfoils built using bent wood top and bottom "chords" connected by wood spacers.

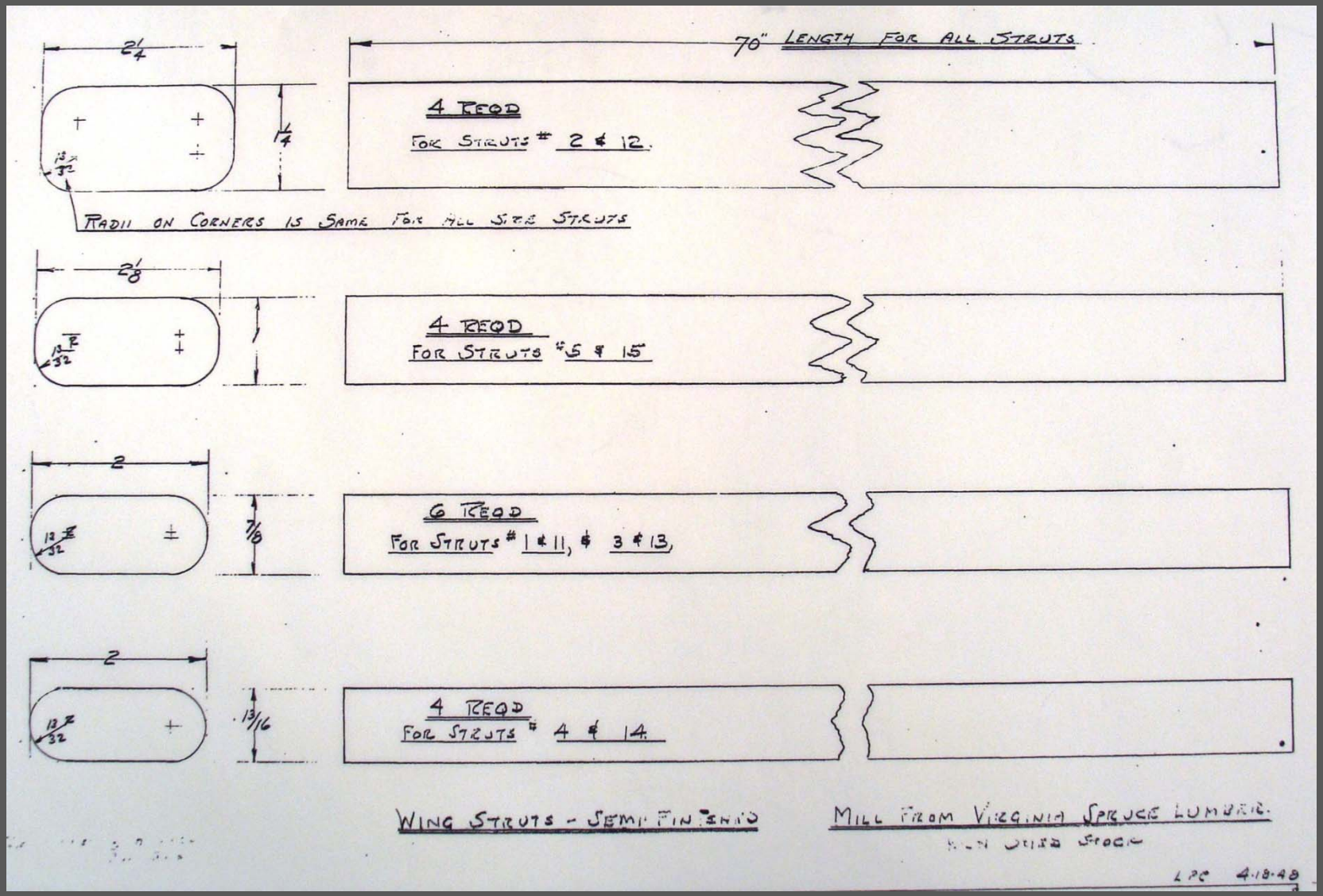
The earlier gliders used single pieces of bent ash, which "lost their curvature as the season advanced."

Wood

“..the static strengths of white pine and spruce agree very closely. We found this also in the tests which we made in 1904. However, we thought we found much greater difference in the shock-resisting ability of the two woods…. For most of our aeroplane work we preferred the *light white spruce of West Virginia.”*

“It would seem to me that some other wood could be used in making the ribs for the aeroplane surfaces. For this purpose some wood of very light specific gravity would be best. The shock absorbing qualities are of no importance in the ribs.

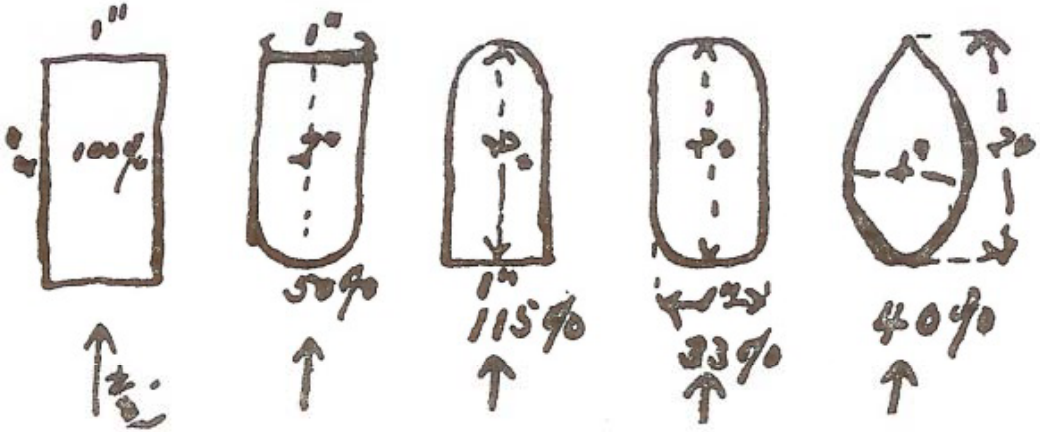
Orville Wright to Carlisle P. Winslow, June 28, 1917



Unequal, non-prismatic compressive struts

June 7, 1903

In testing it with the square corners to the wind and the back edges rounded we got a resistance in excess of the original piece, about 115 percent. The "fair" or fish shape, like that recommended by Mr. Chanute, did not give as good results as that of the piece with the corners simply rounded. These measurements are only applicable



While the numbers given do not really represent the exact percents of efficiency, they give the order of their merit, according to our tests.

to pieces in which the lateral dimension is one half of that of the fore-and-aft dimension.

Strut cross-section determined from wind tunnel studies

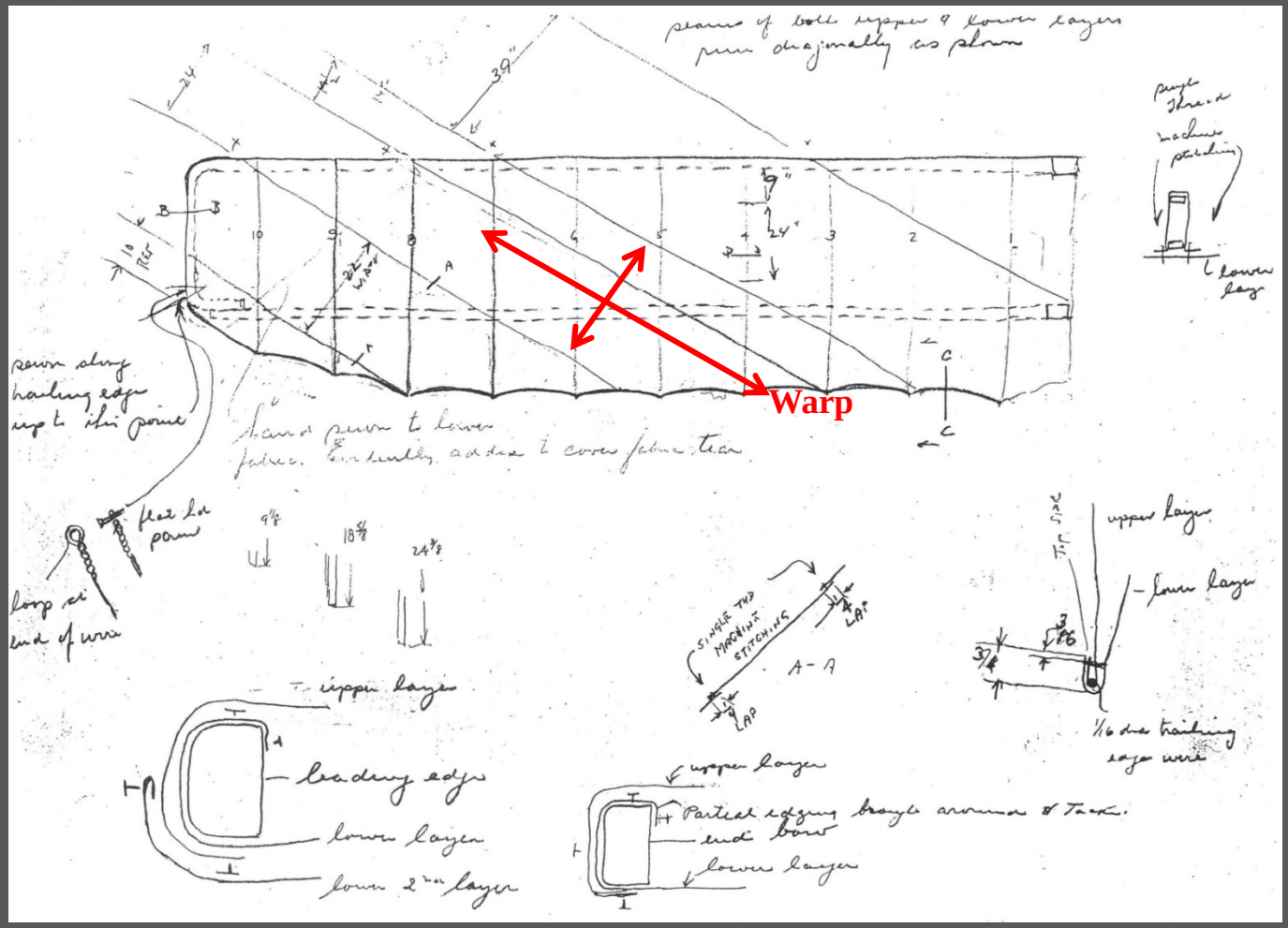
Wire

Hard drawn wire, cold drawn wire, “piano” wire, bicycle spoke wire, spring steel wire

“Roebling wire was used for the trusses.”
Charles E. Taylor, “My Story of the Wright Brothers,” *Collier’s Weekly,* December *25, 1948.*

Wire order for 1947-1949 restoration of the 1905 Flyer III
Standard Steel Wire Gauge, W & M (Washburn & Moen)

300ft	**#18 (0.0475”)**
250ft	**#13 (0.0915”)**
250ft	**#12 (0.1055”)**
250ft	**#11 (0.1205”)**



"The covering of the machine was French sateen, and it was put on a bias so that no wire stays were needed to brace the surfaces diagonally." Wilbur Wright to Octave Chanute, Nov. 16, 1900
All subsequent flyers used *Pride of the West* unbleached muslin, 108 threads per inch; no coating was applied.

Construction of Pratt-type biplanes - Placement and pretensioning of wire diagonals

Why pretension diagonals?

- **Both diagonals “active” increases (vertical) stiffness of wings**
- **Avoid non-linearities when some wires become slack**
- **(and hence) improve “controllability” of machine**
- **Increase the natural frequency of the diagonals (and hence)**
- **Decrease wind-induced vibration of wires**

What level of tension should be used?

- **Prevent slackness under all loadings**

Pretensioning is commonly done by in-line turnbuckles.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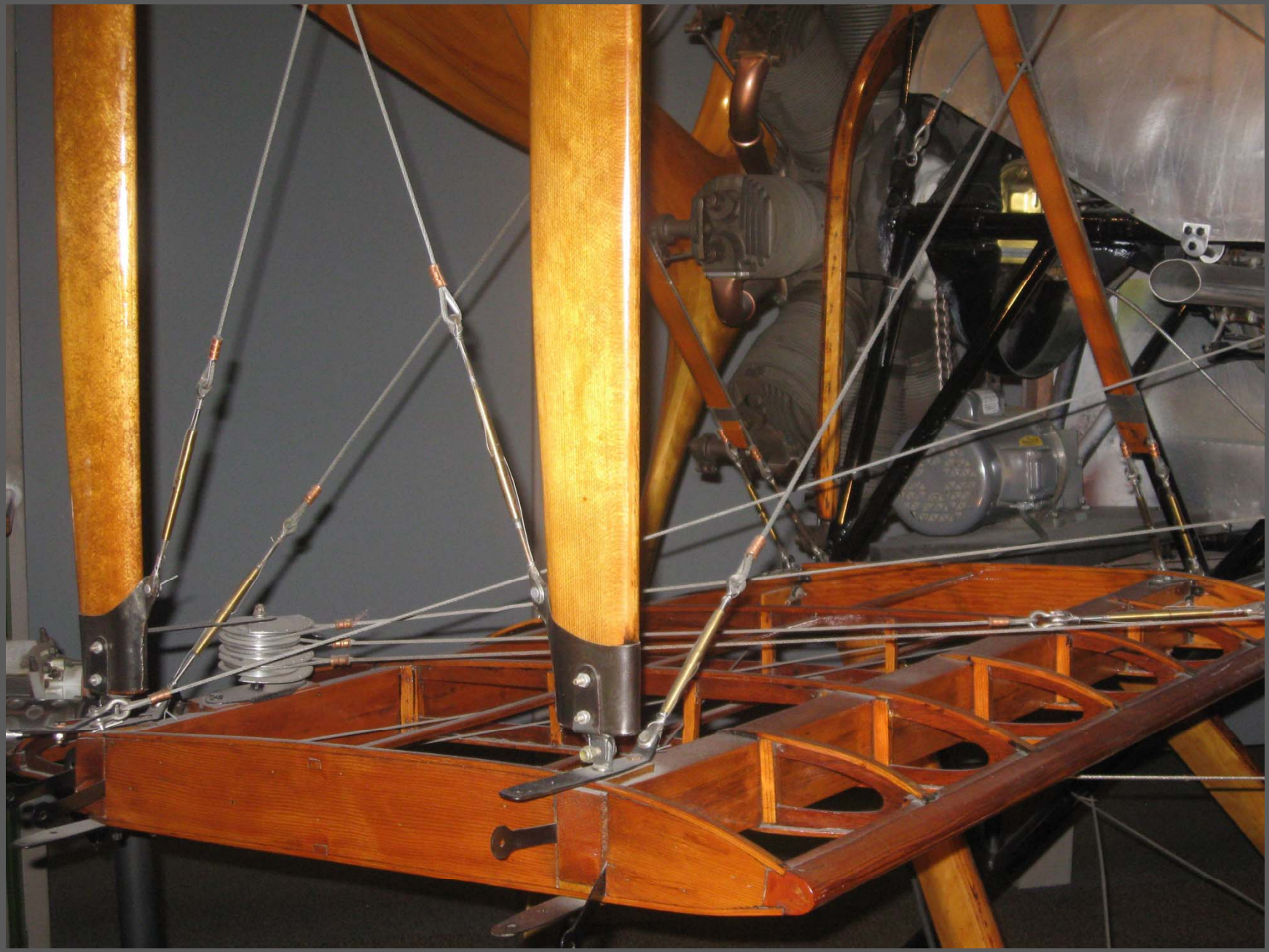
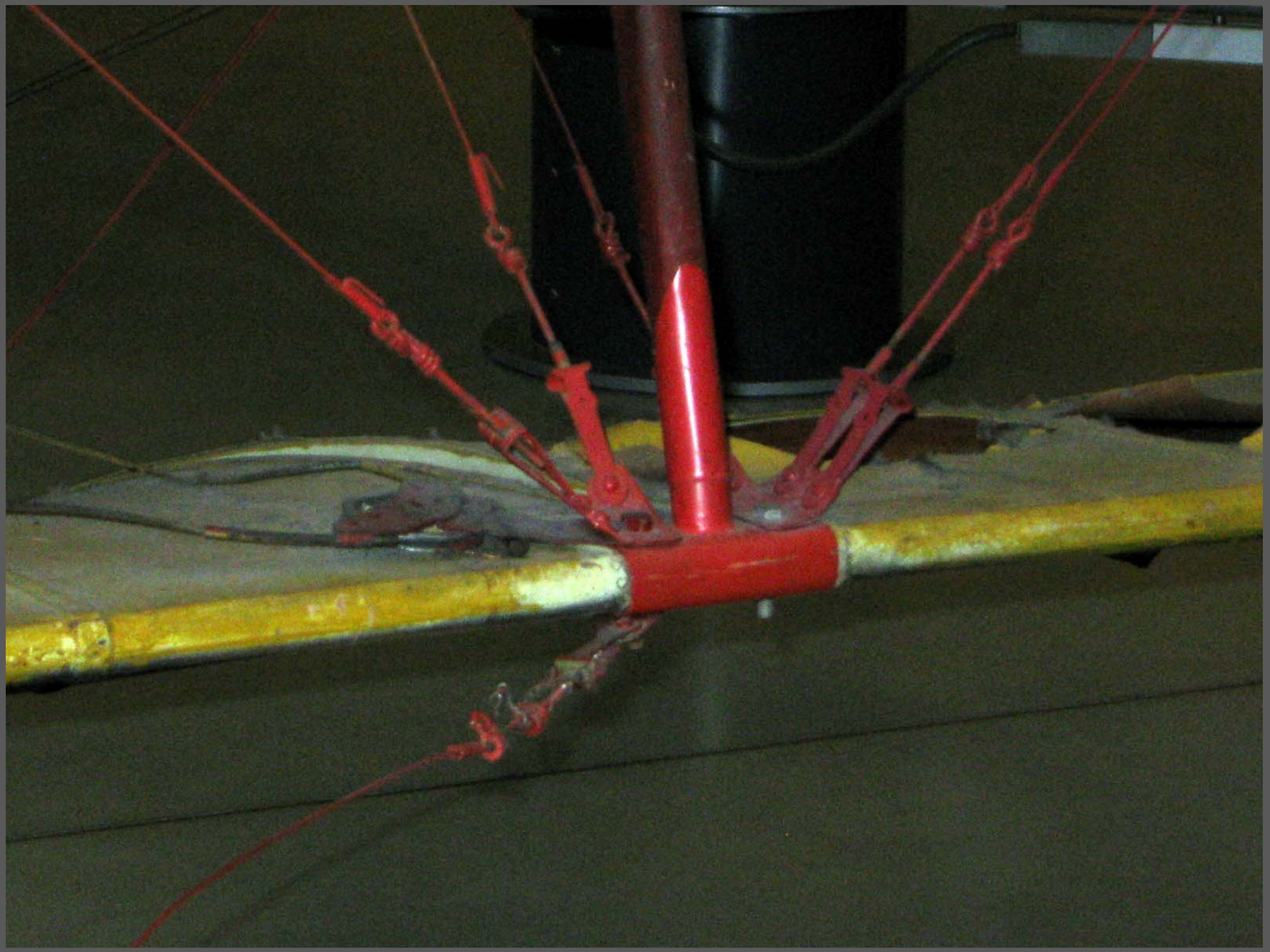
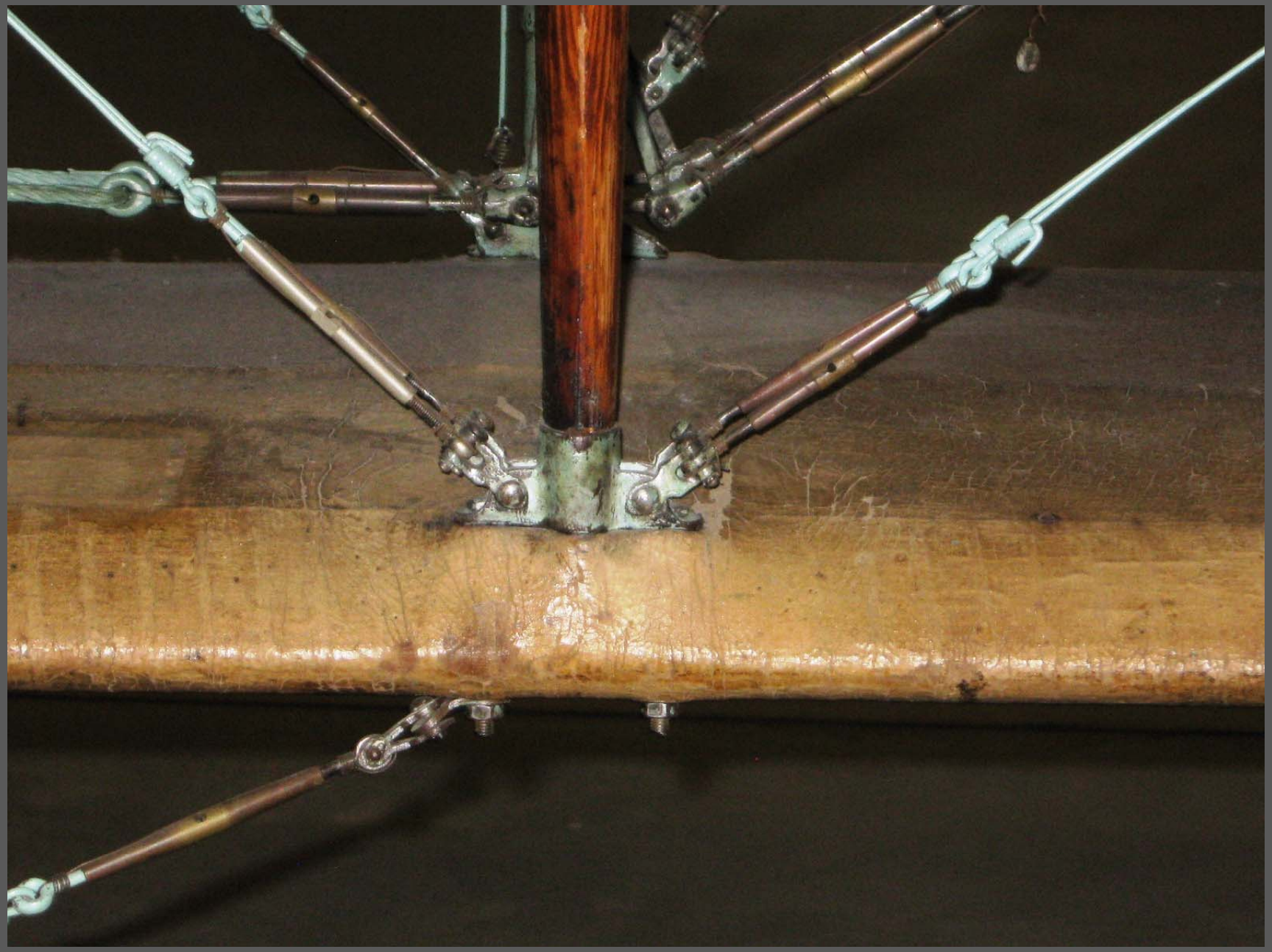






Wright Flyers- Restorations and full-size replicas

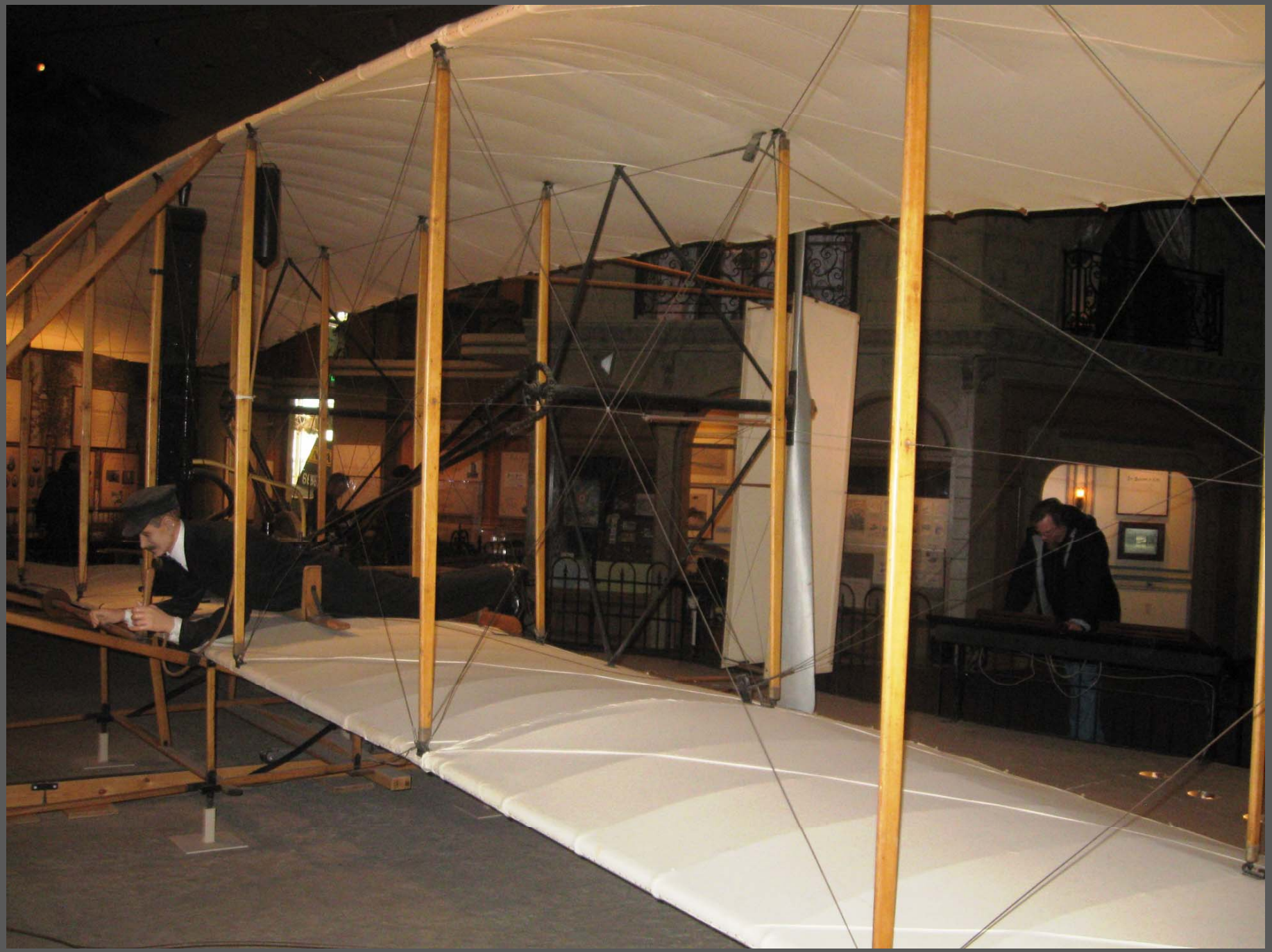
Smithsonian Air and Space Museum – 1903 Flyer I returned to the U.S. in 1948 from London, England (“X% original”)

Dayton History - Carillon Park 1905 Flyer III restored in 1947-1949 by Louis P. Christman with the support of NCR, with initial guidance from Orville Wright (“90% original”)

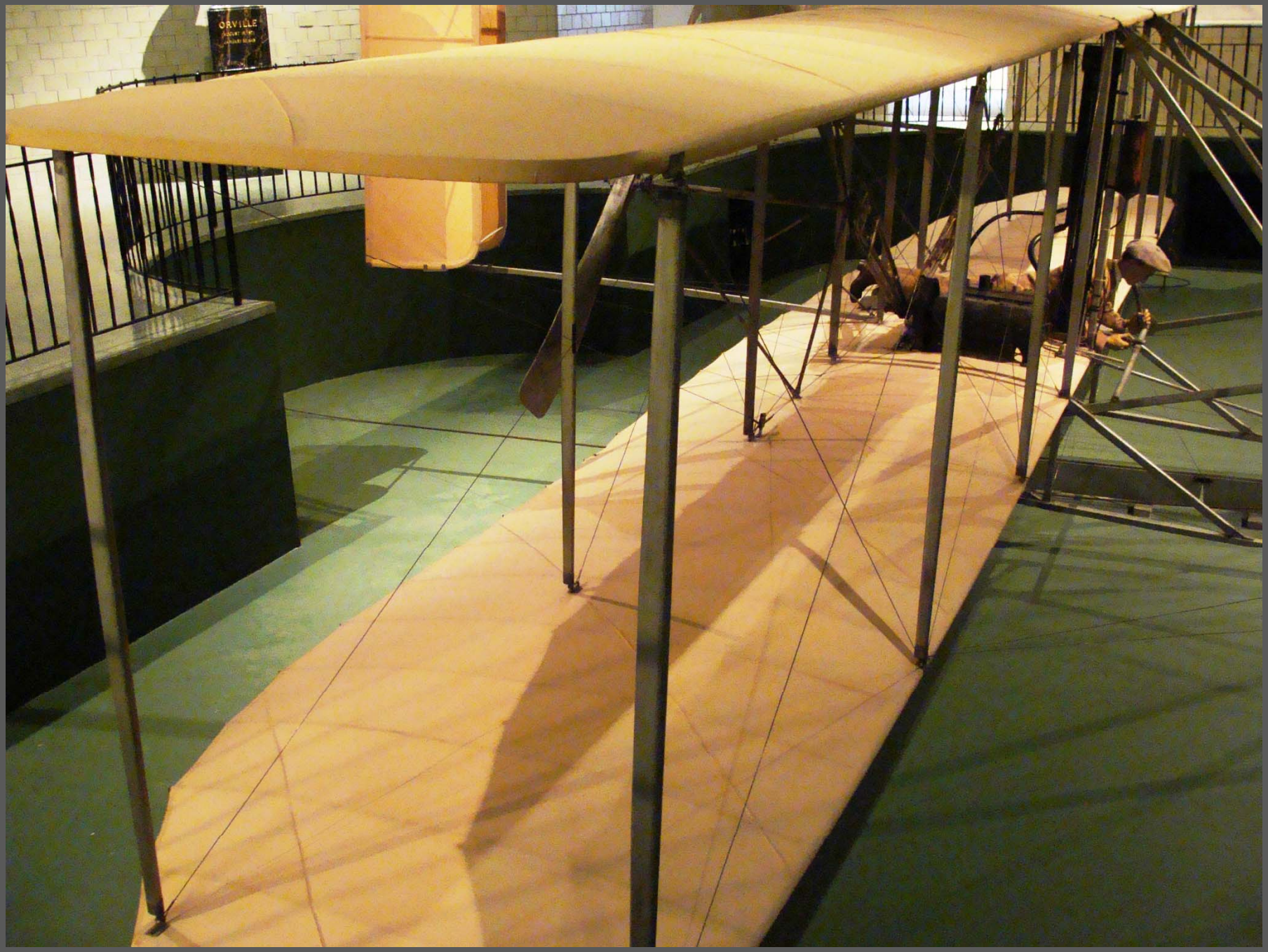
Smithsonian Institution Steven F. Udvar-Hazy Center, Washington Dulles International Airport - replica of the 1903 Flyer I

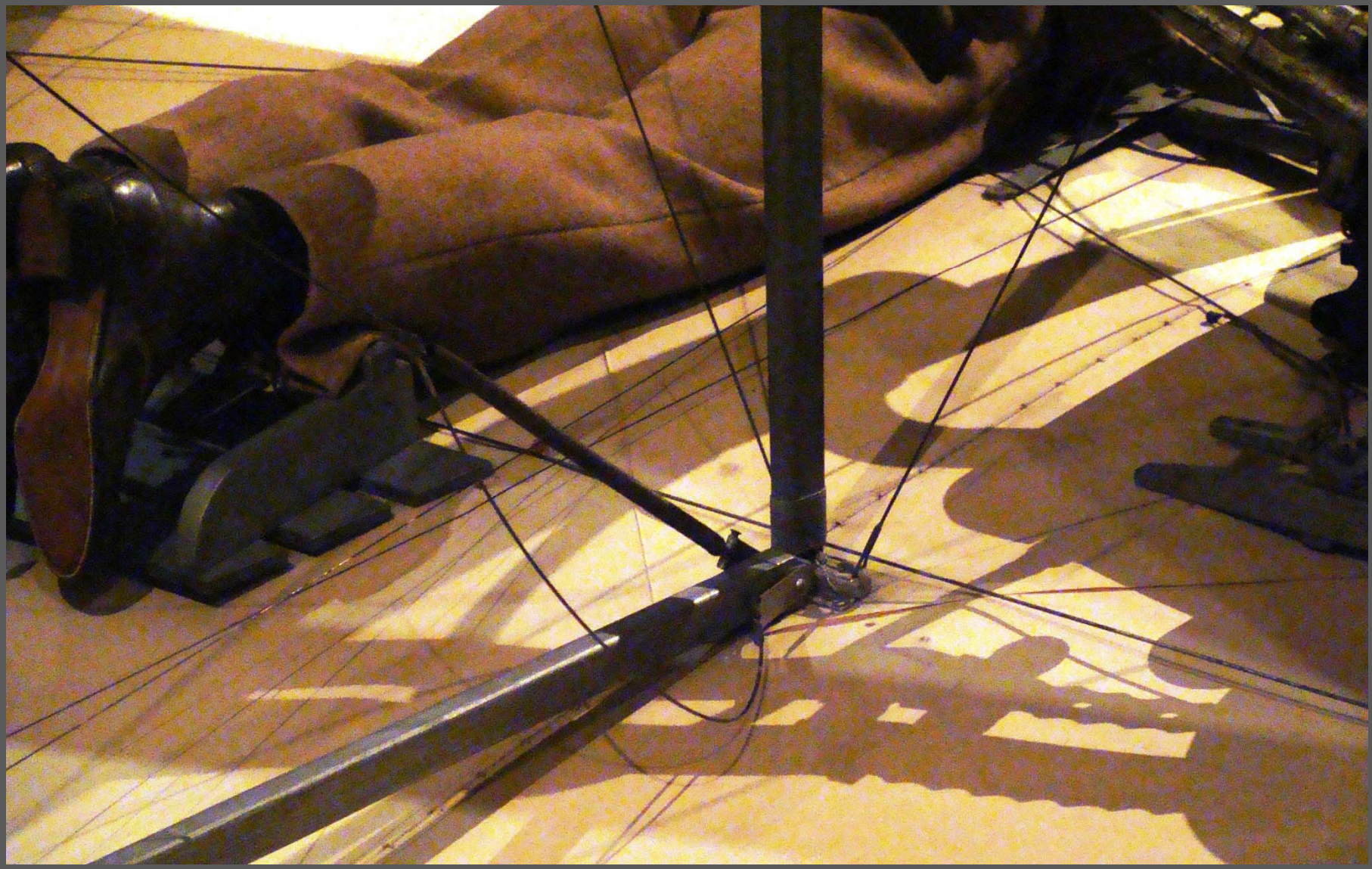
Wright State University – replica of 1903 Flyer I, completed in 2001

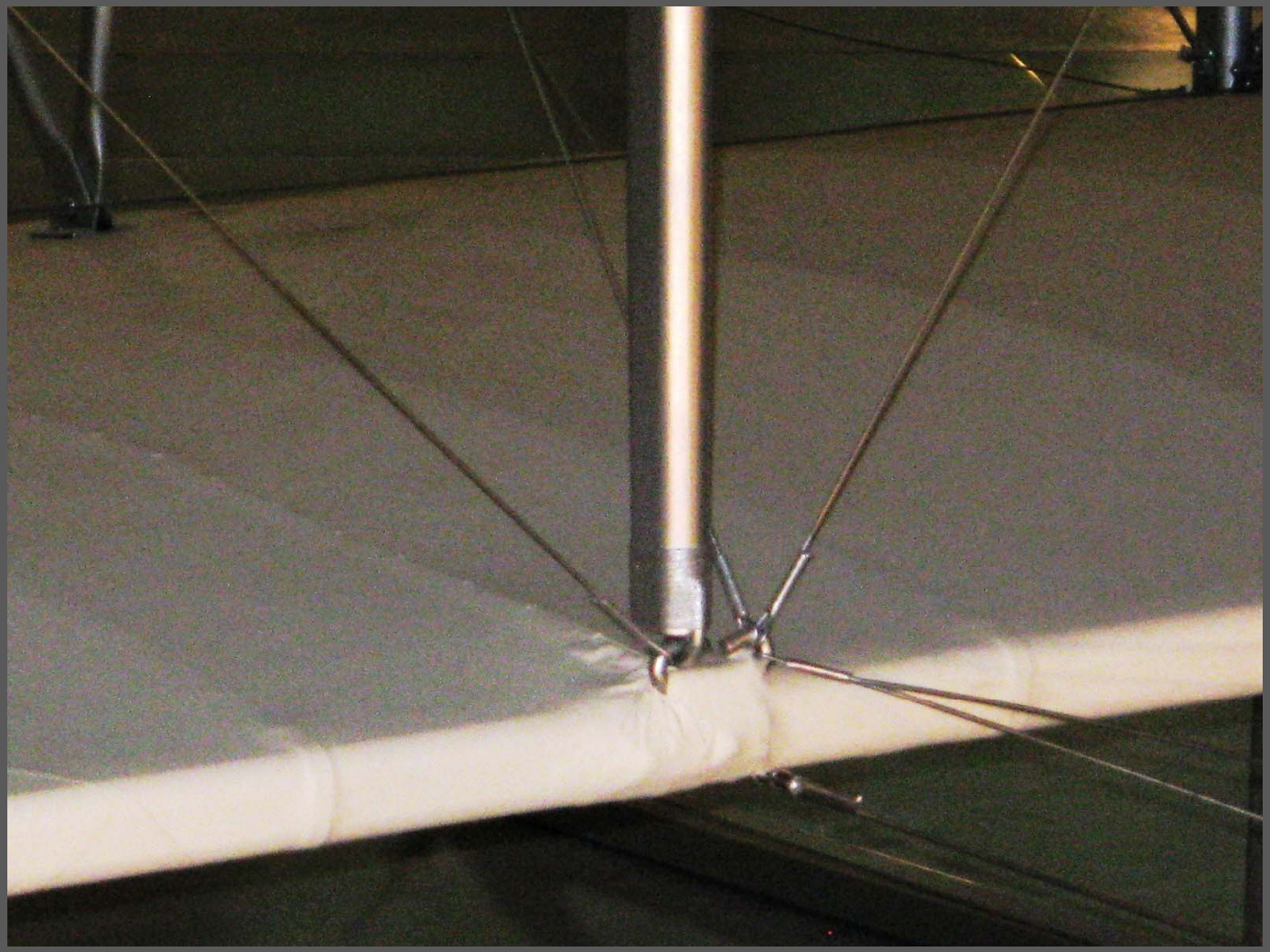
Several reconstructions in 1978 and 2003 in commemoration of first powered flight



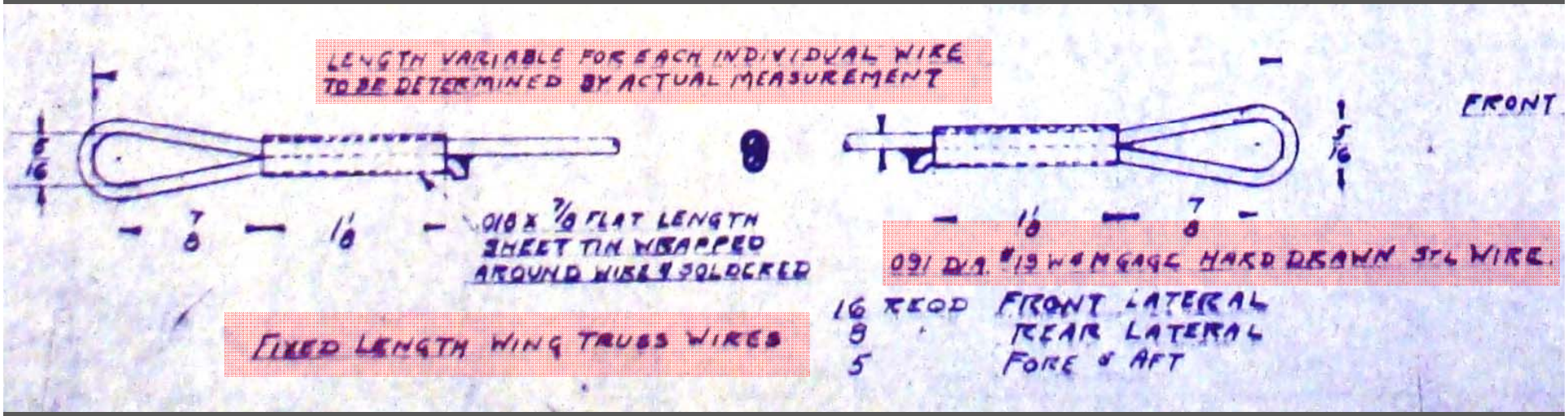
Louis Christman restored the 1905 Flyer III at Carillon Park in 1947-1949 (initially under the guidance of Orville Wright)


ORVILLE





1903 Flyer I replica – Smithsonian Steven F. Udvar-Hazy Center, Washington Dulles International Airport



Blueprint of drawing done c1948 of 1903 flyer

Is it possible to construct a Pratt truss using *only* wire diagonals of fixed length?

Did the Wrights use adjustable-length diagonals *during construction*?

The papers of Orville and Wilbur Wright -1953

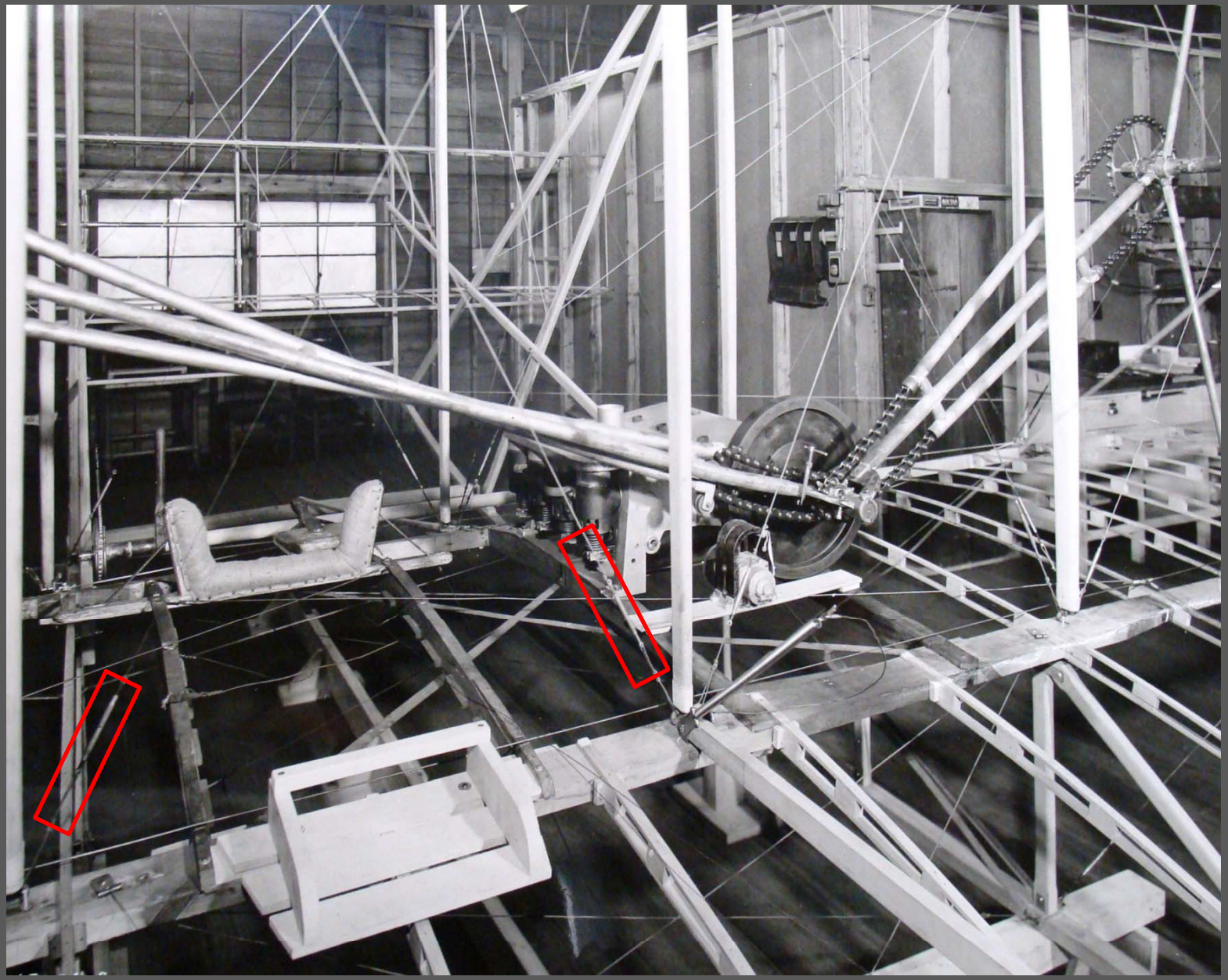
The Published Writings of Wilbur and Orville Wright -2000

Drawings executed in 1947-1949 as part of restoration of the 1905 Flyer III at Carillon Park – Dayton History

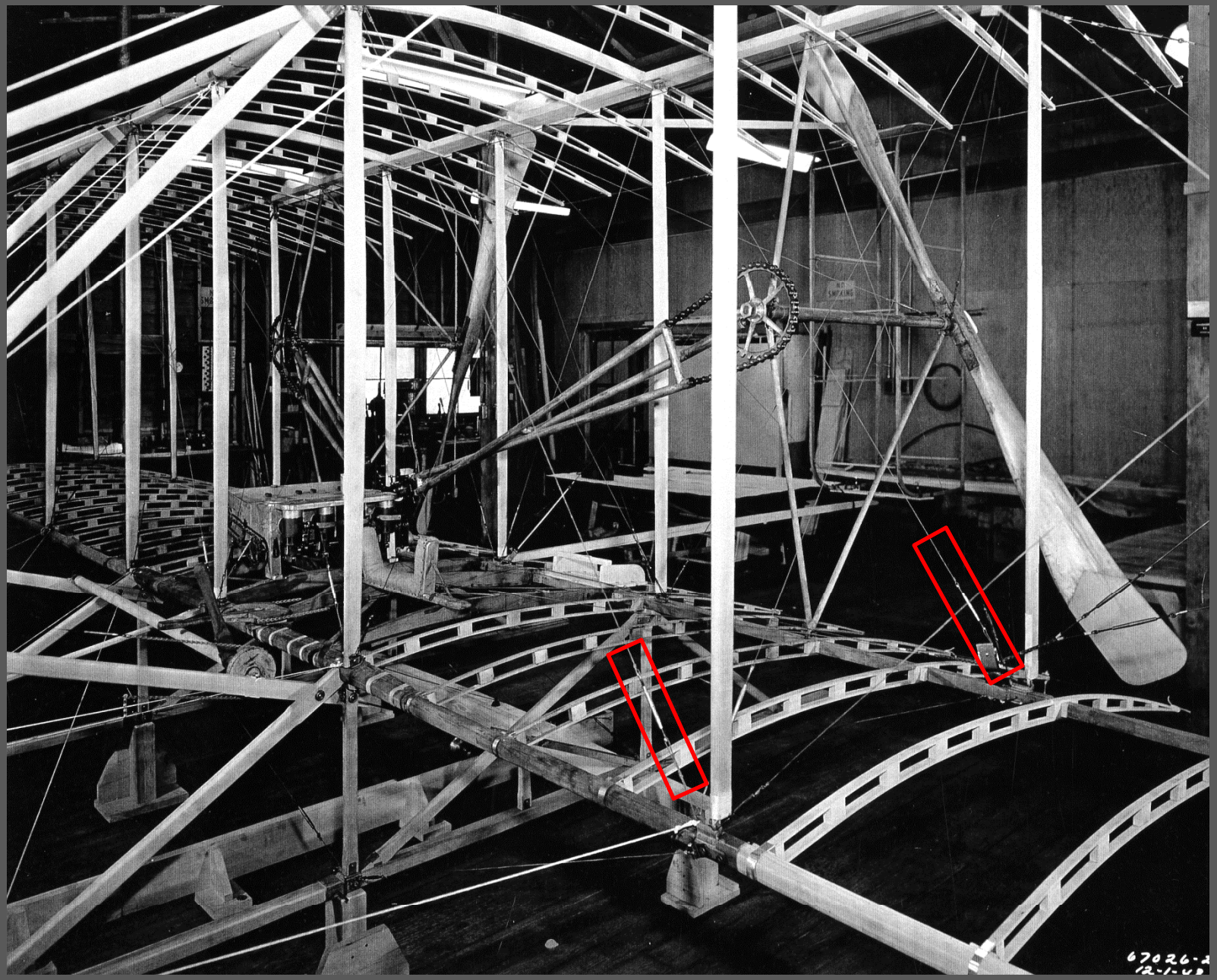
Communications and purchase orders for the 1947-1949 Flyer III restoration

Images of the 1947-1949 restoration and other images

NCR, Smithsonian, and Wright State archives (not examined)



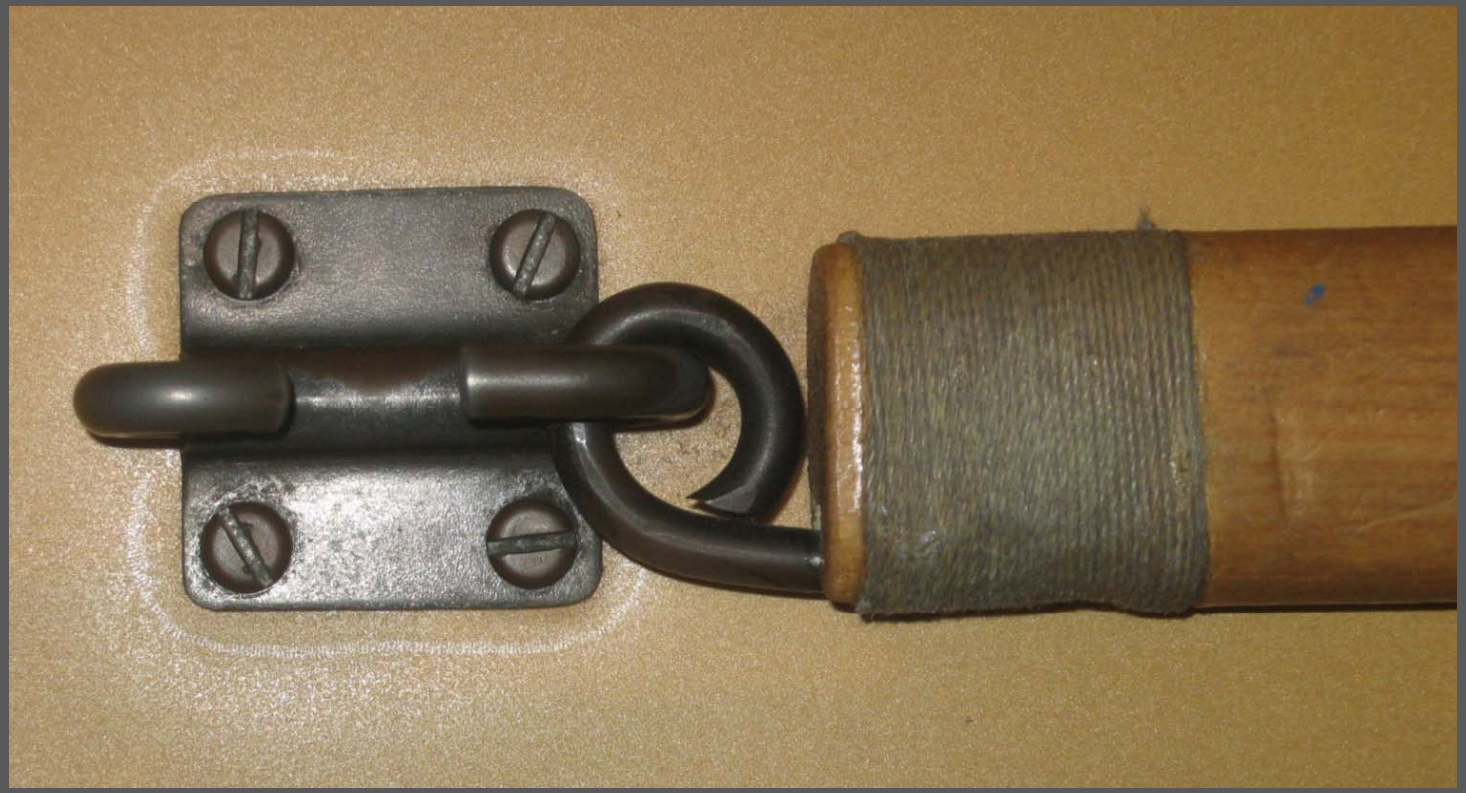
1947-9 restoration of 1905 Flyer III – Carillon Park, Dayton



1947-9 restoration of 1905 Flyer III – Carillon Park, Dayton

A *conjectured* construction sequence….

Wrights used adjustable-length diagonals to establish geometry and pretension. They then measured the exact lengths required. They then pre-made wires with soldered end loops. They installed the pre-assembled fixed length diagonals by slipping the loops over the hooks and finally removed the adjustable wire diagonals.



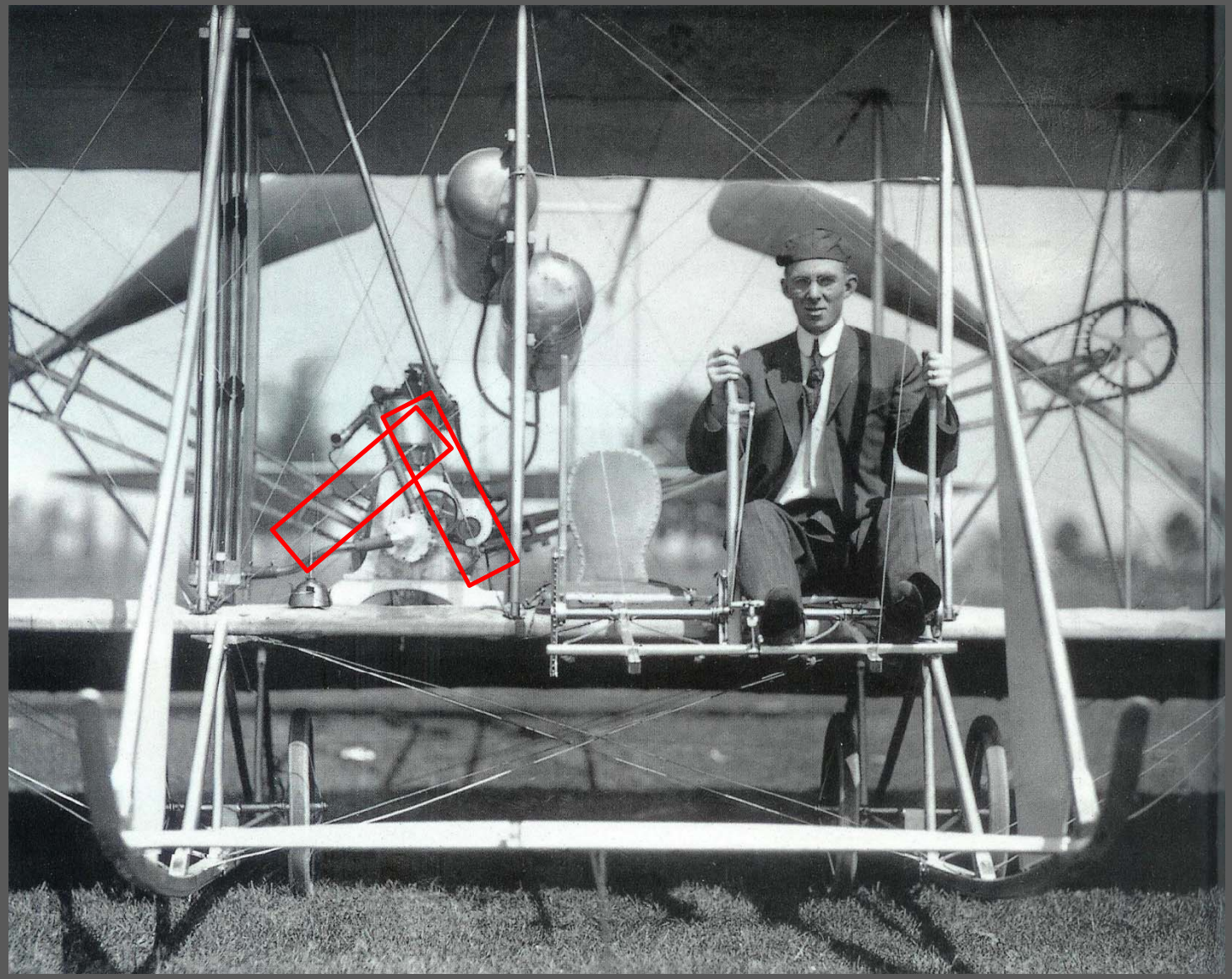
If the Wrights used turnbuckles during construction, why did they remove them?

- **Aerodynamic drag?**
- **Weight?**
- **Appearance/simplicity?**
- **Reliability and strength (simplified four wire joints to two and eliminated the possibility that turnbuckles could become loose)?**
- **Easier to disassemble/reassemble and achieve the same geometry?**
- **Expense?**

Did the Wrights use permanent in-line turnbuckles for the flyers they built after 1905?

1907 - 1909 machines
1909 Signal Corps machine
Model B 1910-1911
Model R 1910
Model EX 1911
Model C 1912
Model CH 1913
Models D to H 1912-1914
Model K 1915
Model L 1916

Photographer William Mayfield after 1910 flight aboard Wright Exhibition Model B Flyer (*Timeline*, January • February 2000)



Dayton engineer and inventor Charles F. Kettering aboard a Wright Model B Flyer at Huffman Prairie in 1913 (*Timeline,* January • February 2000)

Franklin Institute 1911 Wright Flyer Model B – Restored in 2001-2003 by Aeroplane Works, Dayton, Ohio

The Wright Brothers and the Pratt truss

The Pratt truss, developed in 1844 for wood-iron bridges, was a key, essential component of the first powered airplane!

Adopted from the "double-decker" Octave Chanute/Augustus Herring gliders

Design – Surface area to provide sufficient lift, strength and stiffness when in flight and landing, light-weight, allow wing-warping control

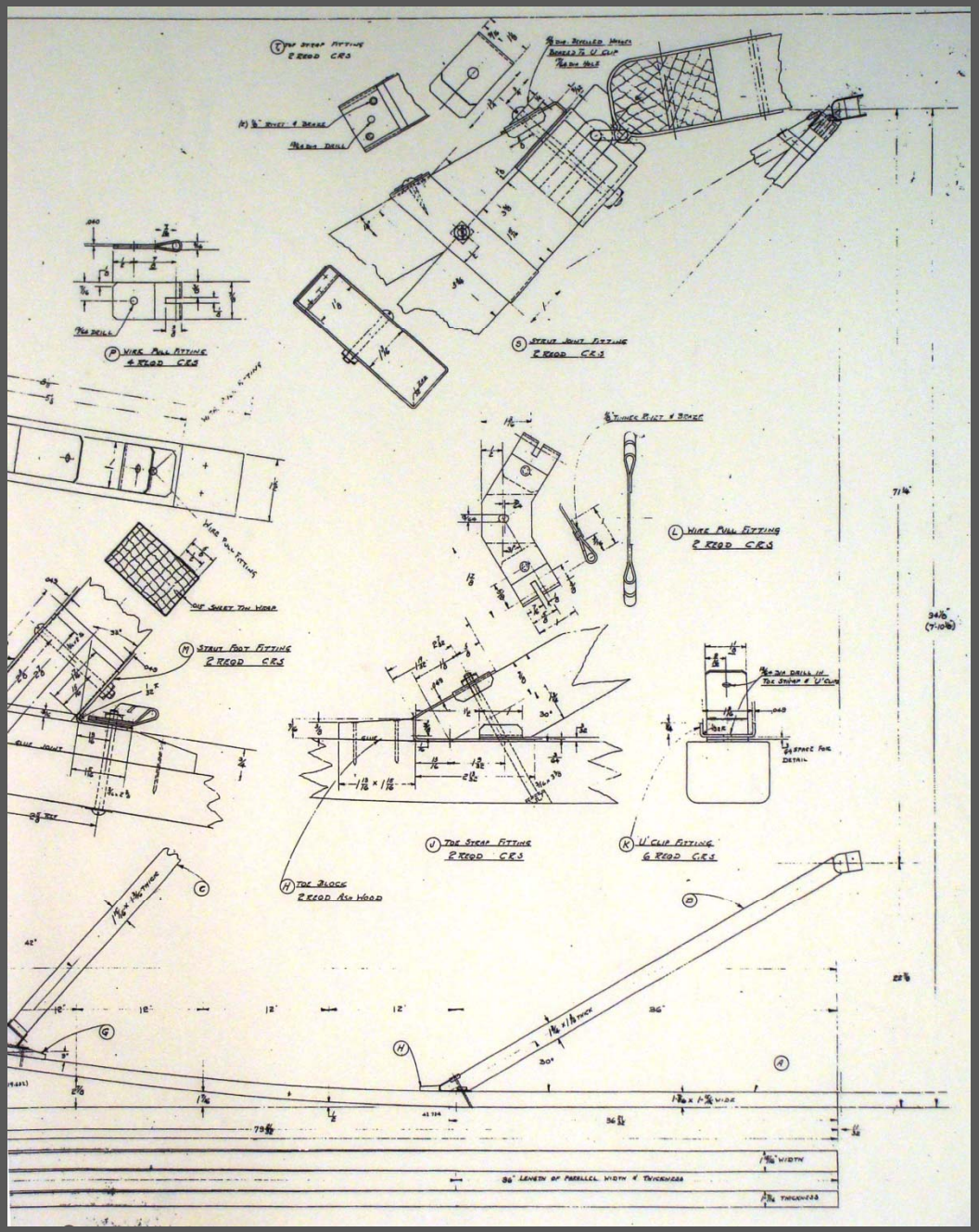
Construction and pretensioning diagonals – Did the Wrights use the method that was subsequently used for the 1947-49 restoration of the 1905 Flyer III (begun under the guidance of Orville Wright)? If so, why did they remove the turnbuckles? Apparently the Wrights did not adopt permanent in-line turnbuckles in general. The 1911 Model B Wright Flyer at the Franklin Institute has fixed length diagonals.

Thanks…

David Simmons from the Ohio Historical Society (my professional Ohio brother)

Mary Oliver, Director of Collections, Dayton History, Carillon Park

Dick Alkire, Aeroplane Works, Dayton, OH


(P) WIRE PULL FITTING
4 REQD CRS
(S) STRUT JOINT FITTING
2 REQD CRS
(L) WIRE PULL FITTING
2 REQD CRS
(M) STRUT FOOT FITTING
2 REQD CRS
(J) TOE STRAP FITTING
2 REQD CRS
(K) 'U' CLIP FITTING
6 REQD CRS
(H) TOE BLOCK
2 REQD ASH WOOD
36" LENGTH OF PARALLEL WIDTH & THICKNESS