Highlights	Items
▪ History of the Evolution of the Truss ▪ Clairborne / Pell Bridge	▪ Reed Boats on Nile to Man's trip to Mars ▪ Longest Suspension Span North of New York City

SPANS

Hillsborough County Florida
Bridge Team

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Sailing to Mars

Late in 1989, a small, bridge consulting engineering firm landed a sub-contract with the giant Boeing Company for design work on Boeing Aerospace's Manned Mission to Mars - The Pathfinder Project - for NASA. The conceptual scenario for this trip was to launch the space shuttle and transport the components for the space vehicle to an intermediate assembly site in low earth orbit (LEO). Subsequently, the space vehicle would travel the three million miles to Mars with the aerobrake truss attached. This particular scenario envisioned the breaking mechanism to be a shield to slow the descent of the space vehicle for a soft landing at the planet's surface as it entered the carbon dioxide Marsian atmosphere. The shield would be stiffened by a backing truss that was the subject for the bridge consultant's sub-contract.

The scope for the sub-consultant was to design the joints for the breaking truss so that they could be assembled in the zero gravity (g) environment of LEO, by hand or by robot, and without the use of tools. Curiously, NASA further stipulated that the consultant had to research and provide a narrative description of the origin, evolution and development of the truss beam.

It is evident to us that a boat is a beam which spans between wave crests. We further recognize that a truss is a beam made of small pieces that span large distances. And, we know that a sail boat is a form of a truss. Truss origin can be traced back through 8,000 years of

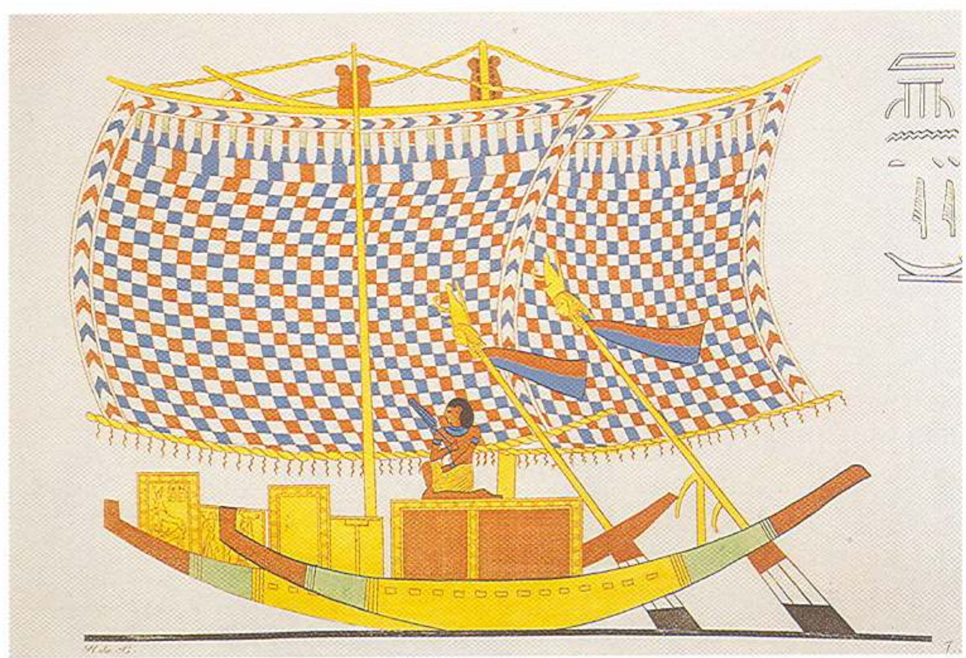


Figure 1: Isaiah's Old Testament reference to reed boats with sail carrying emissaries on the Nile River (740 BC)

recorded history to Egypt, where seasonal flooding covered the Nile River with floating reeds which were one day gathered into bundles and used for constructing boats.

There are pictures on tomb walls dating between 6,500 - 5,500 years ago (Figure: 3) showing a single mast sail boat having one yardarm and one sail all trussed in place with a fore-stay, a back-stay and shrouds. Originally, these hulls were of reed construction which presented certain problems for the mast. Stepping the mast on a reed hull required the Egyptians to employ a tripod mast or even an A-frame to help stabilize the mast and minimize the point loading. The reed hulls were bundled and pinched at each end and, due to the reduced buoyancy at the ends, had a tendency to droop which was unsightly and impractical. To counter this condition, these early shipwrights looped a continuous papyrus rope around each end of the hull and inserted struts between the rope and the hull. The consequent tension in the rope lifted the ends, like a bow and arrow.

The discovery, in 1954, of a cache for cedar timbers in a vault carved from the rock at the base of the Great

Pyramid of Giza (Figure: 2) proved to be the planks of Pharaohs' 47 century old barque. A wood hull provided hard points for the attachment of the trussing mechanism of a sail. Moreover, the enterprising Egyptian boat builders had no nails, bolts or rivets to connect the wood timber so they joined the hull planks by tying together their cut ends with rope. Obviously, the hull was still not functioning as a monolithic, ridged plate and the bow and stern still tended to droop. The fore-stay and back-stay of the single mast served the dual purpose of acting as a hogging truss and a mast truss for the sail.

The amazing thing about the single mast, square sail boat is that it remained unchanged for 5,000 years and not until the Renaissance were more masts and more sails utilized by the shipwrights. The next 400 years saw the proliferation of masts and sails culminating in the great Clipper Ships of the nineteenth century. The magnificent square rigged ships plying the high seas in the 18th and 19th centuries could reduce the five and six courses of square sails down to their lower masts when required by weather and/or military action, in less than two minutes. During practice sessions, the skipper would record the time and number of casualties incurred during this exercise. These yardarms could weigh up to 2 tons and some warships had crews of 800 men. (The dismantling of five and six courses of sails and their standing rigging in less than two minutes is no less impressive that the assembly of the aerobrake in LEO.)

Correspondingly, with the advent of the steam engine and railroads in the eighteenth century, the truss beam took on many shapes and sizes in order to accommodate the gradual grades and narrow alignments required by these dedicated roadway networks. First, the stone bridge gave way to the wood truss and then the rapid transition through cast iron, wrought iron, and then to steel trusses has seen truss technology reach an advanced state of development.

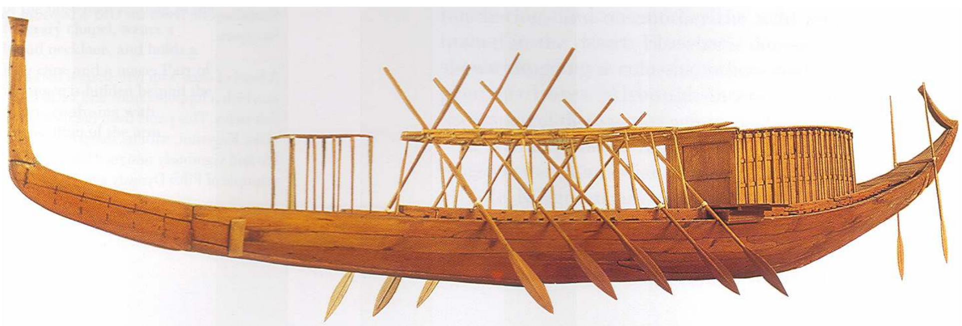


Figure 2: Forty seven century old timbers recovered, reassembled into original shape without spikes, rivets or pegs.

Today, anyone can speak of space travel without raising eyebrows. Man has achieved considerable success in space science and applications. He has made giant steps in space travel and here we find ourselves designing a vehicle to transport man to the fourth planet from our sun.

The Pathfinder Project's contract scope requirement for the aerobrake design was that the nodes sustain a 6-g atmosphere entrant loading while connecting the matrix of strut and tie elements which composed the breaking shield's backing truss. These truss elements, cylindrical in cross section, were to be made of carbon reinforced fiber (CRP). It was unexpectedly discovered that this material, when in LEO, would rapidly corrode because there were free oxygen molecules present which would attack it like Pac-Man[c] . The solution was simply to apply a thin film of metallic paint to these elements. Extra vehicular activity assembly of the aerobreak truss, as imagined, would be from the center outward toward the limiting perimeter of the truss' projected area. The assembly method would either be stick by stick or by preassembled packages

The connection ends for the strut and tie elements were designed to be capped with titanium fittings to match the precision, titanium nodal castings. The typical configuration of these elements was two frustums separated by a cylindrical, length-adjustable spacer. The frustums had their small diameters at the nodes and their large diameters faced the mid-length of the strut and tie element. There were seven alternate node designs. Only one of them had the functional capability for torsion adjustments and it was made rigid by epoxy injection. The other six designs were variations on a mechanical connection.

This prototypal design brought to the surface unanticipated concerns such as delivery cost. Transporting 6 inch diameter pipes in the 60 foot long by 15 foot diameter shuttle bay was comparable to shipping a truck-load of potato chips. It was determined that cones provided a denser load than the prismatic pipe elements, hence, the back to back frustums. These pieces could be, consequently, telescoped into a more efficient volume to weight ratio. The high strength to weight ratios of the CRP also contributed to the minimization of the delivery cost per volume of cargo.

With a time-line established for the evolution of the truss and the current understanding of the exceedingly rapid technological development of materials, we may get a better idea for anticipating future directions. This is important since inter-planetary travel will be measured in years and we must prevent our space travelers from falling behind "the curve" during their extended absences from our planet.

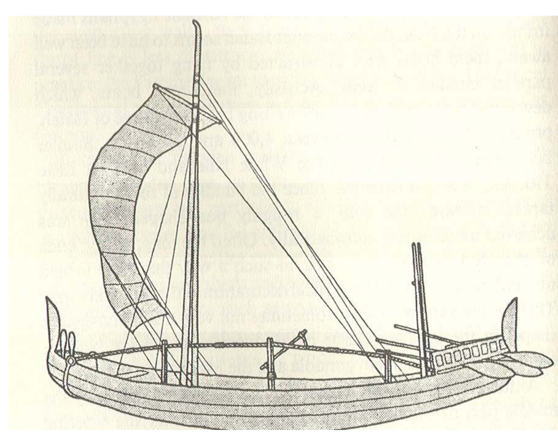


Figure 3: 2,500 B.C. depiction of Egyptian, wood hulled, sailboat.

For example, recent developments in ceramics may have suggested that the use of metals was becoming obsolete. However, parallel developments in metal processing techniques have progressed at an unexpected rate with the application of new processes such as super plastic forming, rapid solidification, and mechanical alloying which have increased the strength and durability of this material. Consequently, metals have returned to a new, competitive position.

With the conclusion of the human crew's three million mile ride and arrival on the Red Planet's surface, we see another facet to this most complex equation for survival. Beyond the aerobreak research is another universe of questions relating to Terra Forming. Work is underway to convert the Martian atmosphere into a more earth-like environment in order to sustain colonization from earth. Consider this apparent paradox. The Martian atmosphere presently converts water directly from a gas to a solid without the intermediate state of a fluid.

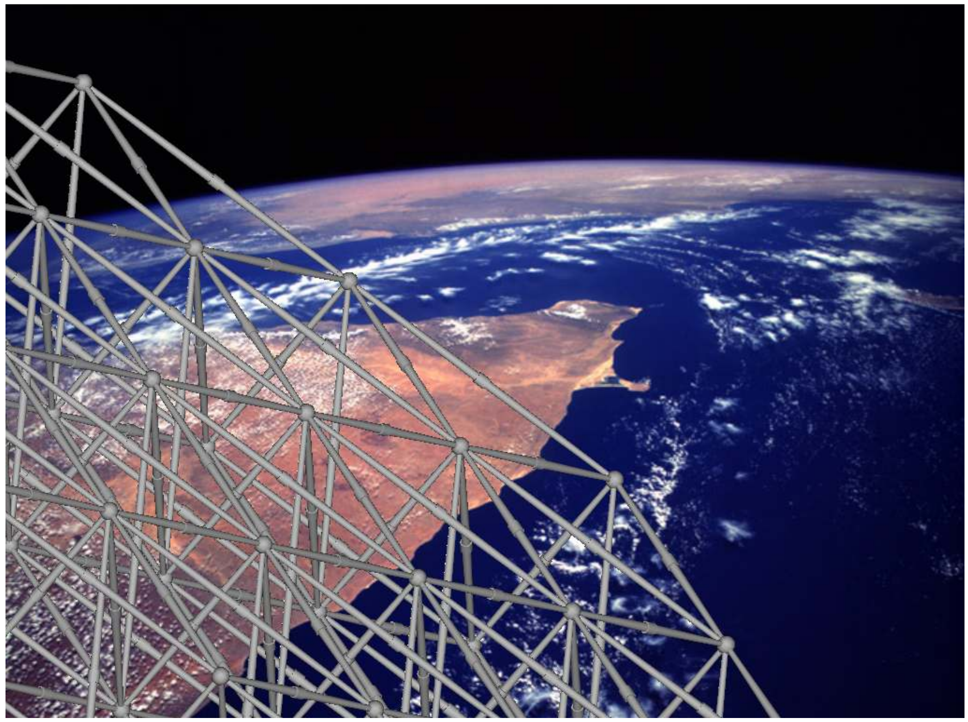
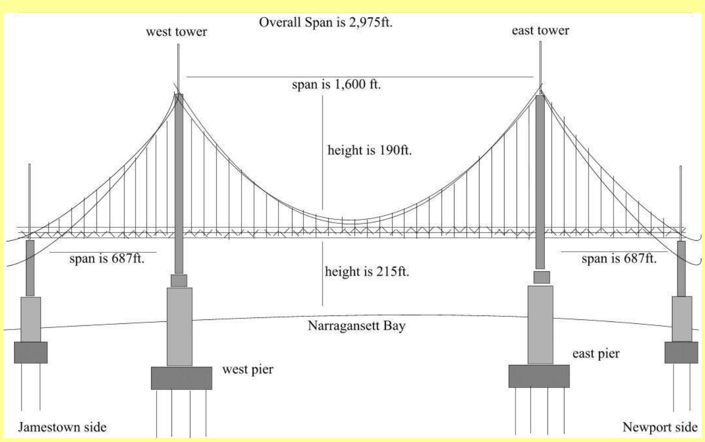


Figure 4: Depiction of Path finder Aerobrake Truss assembled in Low Earth Orbit without shield.

However, the evidence being beamed back to earth strongly suggests that water was flowing on the Martian surface in the past. Can we make it flow again?

The Clairborne / Pell Bridge

See Guest Commentary, next page



Congratulations, Mr. Silano, on your Lifetime Achievement Award in Design. This recognition by our American Society of Civil Engineers (ASCE) with your designation as the OPAL Award winner for Design is most appropriate. With compliments,

SPANS.

Guest Commentary

Not a Two Bit Bridge

By: Louis G. Silano, P. E.

When I was included on the design team for the two mile crossing of the east passage of Narragansett Bay, between Jamestown and Newport, Rhode Island, I had no vision beyond doing an important job and doing it well. Today, the United States Mint has produced the distinctive image of the gothic towered suspension bridge millions of times in the form of the commemorative twenty five cent piece for the state of Rhode Island. The Clairborne / Pell Bridge, within the total length, includes a suspension bridge over the main shipping channel to the Atlantic Ocean. The suspended center span is 1,600 feet long with side spans of 687 feet in length. The center span provides for a clear horizontal width of 1,500 feet and a vertical clearance of 205 feet.

The present alignment and structure was the culmination of studies for 35 locations and span configurations. Suspension bridges are typically composed of five distinct parts: foundations, towers, cables, suspenders and a stiffening truss. The foundations for the main span were challenging in that they were located in water 100 to 140 feet deep which rendered full depth cofferdams impractical. Consequently, it was decided to use open box forms placed over pile foundations starting at the channel bottom followed by hollow pier shafts to the surface. Then, the complete footing and pier shafts were tremie concreted to within 15 feet of the water's surface where a follower cofferdam was attached permitting this 15 feet of pier to be carried to it's final elevation in the dry. The steel tower anchor bolts were installed within this dry concrete pour. The structural type selected for the suspension tower legs was a modified, rectangular-cruciform, welded, cellular, steel box section crowned with the gothic arch portal strut all topping out at an elevation of 371feet 9 inches.

Historically, the installation of the cables for suspension bridges has taken two forms: cable spinning from anchorage to anchorage across all supports; and, the pre-manufactured, socked, helical wire strands that are delivered to the site for installation. The new technique, first used on the Clairborne / Pell Bridge, combines the best features of both methods.

Parallel wire strands are fabricated in the shop, cut to their proper length, socketted, placed on reels and delivered to the job. At the site each strand is anchored, carried over the saddles at the cable bent piers then the tower saddles and back to the opposite anchorage for attachment. After all strands are put in place, in accordance with this process, and in their specified locations within the cable cross-section these strands are compacted into their engineered cross section of 15-3/8 inches diameter. Each of these cables is subjected to loads up to 6,400 tons.

The four twelve foot wide lanes are supported on a seven and a half inch thick, reinforced concrete roadway by wire rope suspenders which are looped over cable bands clamping the suspension cables. All suspenders were pre-stretched to 50% of their ultimate strength to eliminate inelastic stretch. Additionally, these ropes were measured for socketing at 68 degrees Fahrenheit while under a tension load of 22 tons to simulate the average dead-load stress in the suspenders. The stiffening deck-truss that also collects gravity loads from the roadway is all welded except for the field splices using high strength bolts. Primary horizontal elements are box sections with the interlaced diagonals and verticals composed of welded I sections.

The bridge was opened to traffic on June 29, 1969.

Note: *See page 3 for bridge elevation and bridge photo*

Coming Issues:

- The Gibraltar Bridge with computer monitored and actuated wind stabilizing airfoil
- Denmark's Storre Belt Suspension Span

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A Special Thanks to our Guest Commentator
Mr. Louis G. Silano has been with P.B.Q + D for over 50 years. He is a Senior Vice President and Chief Technical Officer for this Major Civil Engineering Firm

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PASS-IT-ON, Please!