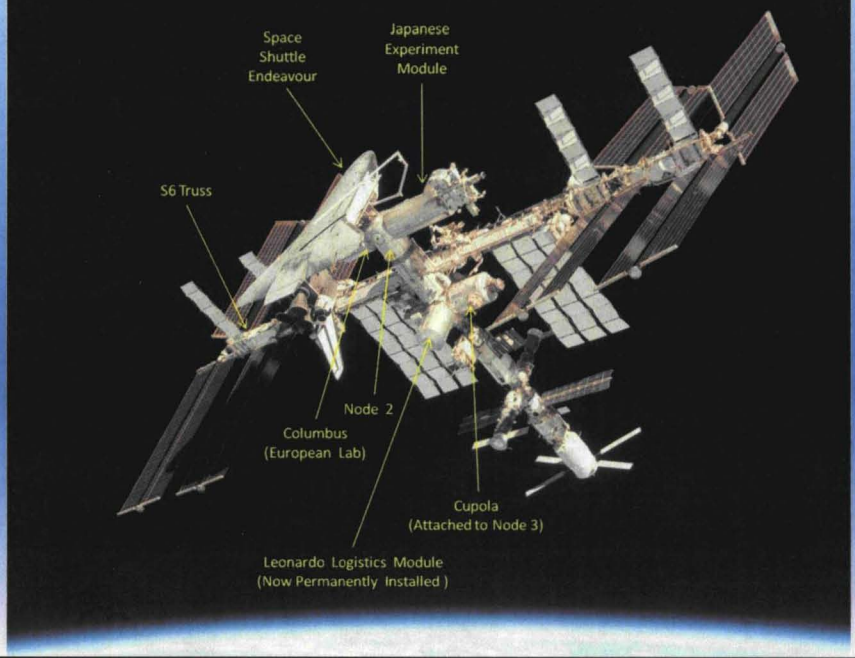
Project Management Issues from Engineering History

Glenn Perez

NASA - Kennedy Space Center



Common Among Successful Large Scale Historical Engineering Projects

- Failed Earlier Attempt
- Initiated by an Innovative Leader with a Vision
- Difficulty in obtaining financing and authority to proceed
- Political Issues
- Behind Schedule and Over Budget
- Problems with Materials not meeting specifications
- Lack of Understanding of New Technology

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Initiators

- Theodore Judah – Transcontinental Railroad
- John A. Roebling – Brooklyn Bridge
- Vicomte Ferdinand De Lesseps – Panama Canal
- Gustave Eiffel – Eiffel Tower

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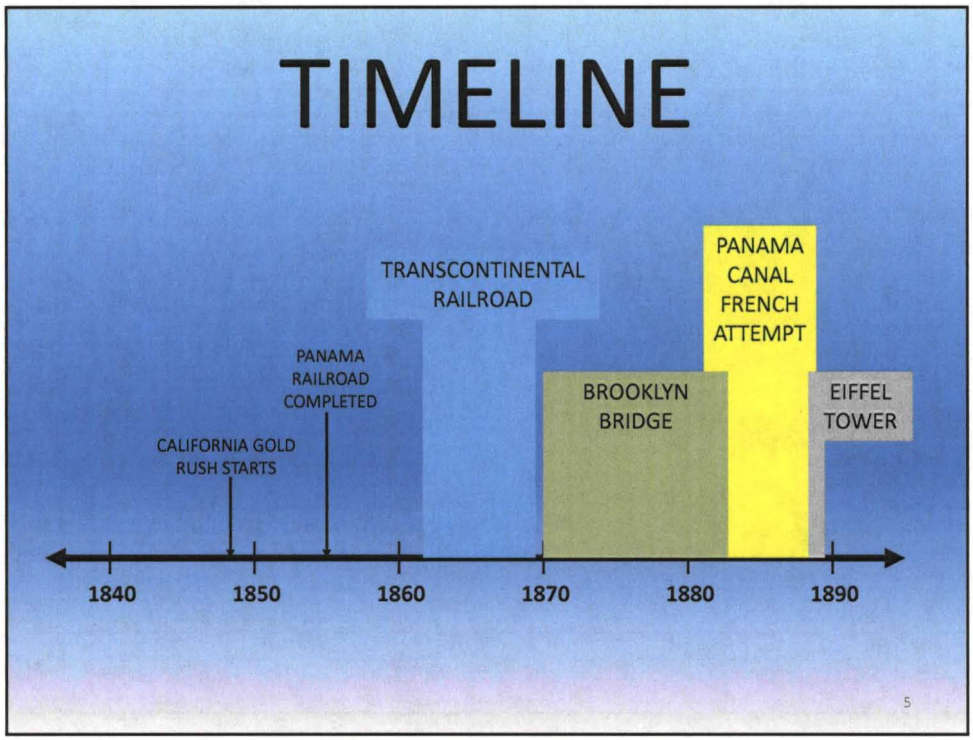
TIMELINE
TRANSCONTINENTAL RAILROAD
PANAMA CANAL FRENCH ATTEMPT
PANAMA RAILROAD COMPLETED
BROOKLYN BRIDGE
EIFFEL TOWER
CALIFORNIA GOLD RUSH STARTS
1840
1850
1860
1870
1880
1890
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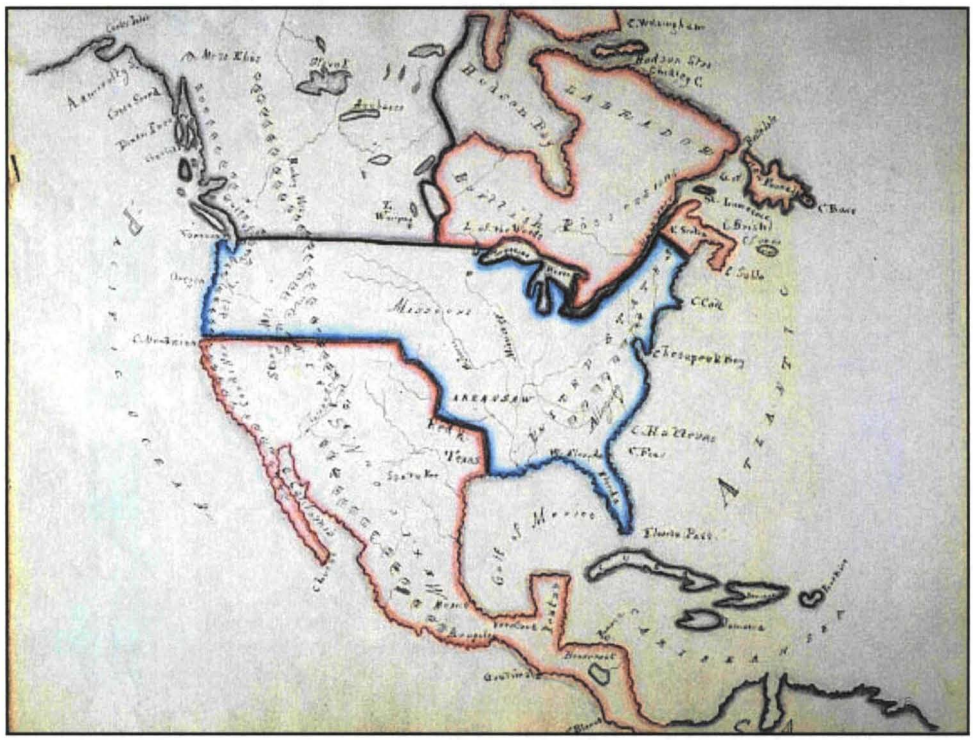

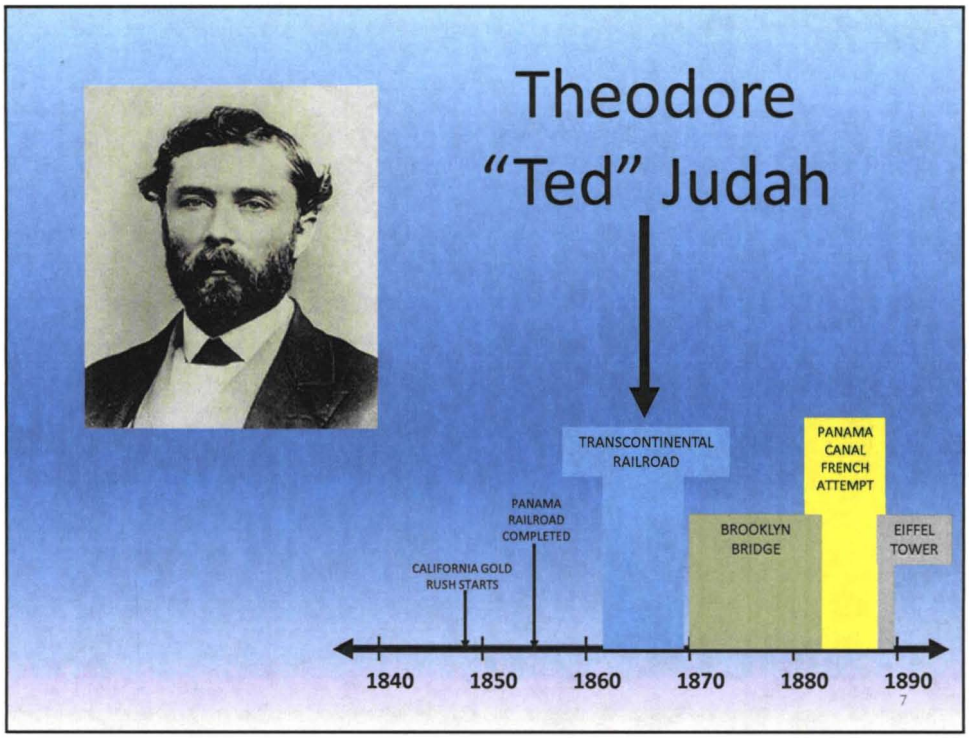

Ted Judah

- Schooled in the Northeast, he was a well-known civil engineer designing and building railroad lines by the early-1850s.
- Moved to California in 1854 to work on the Sacramento Valley Railroad.
- Scouted and surveyed the route over the Sierra-Nevada mountains through Donner Pass that would be used for the transcontinental railroad.
- Worked with local businessmen obtain financing and form the Central Pacific Railroad Company to build a railroad along that route.
- Served as secretary for both US House and Senate Railroad Bill committees, promoting the bill that provided federal land and loans for the building of the Transcontinental Railroad.
- President Lincoln signed the Bill into law on July 1, 1862.

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Tragedy

- Ted Judah died of Yellow Fever in New York City on November 2, 1863. He had caught the disease in Panama while in route from California.
- Judah had been mentoring engineer Samuel Montague. He was quickly promoted to Chief Engineer.
- As the "do-it-all" visionary, Judah had inspired others to initiate the construction. With the Federal Railroad Bill mandates in place, construction on his dream was initiated.

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The Gauge Debate

US Railroad Gauges in 1861

Track Gauge	Miles of Railroad Track	% of Total Mileage
4′ 8-1/2″	17,712	53.3
4′ 10″	3,294	9.9
5′ 0″	7,267	21.8
5′ 6″	2,896	8.7
6′ 0″	1,777	5.3
Others		1

Source: Robert L. Frey, ed., Encyclopedia of American Business History and Biography, Railroad in the Nineteenth Century, Bruccoli Clark Layman Book, 1988, p. 343

- The Pacific Railway Act of 1863 established the gauge for the Transcontinental Railroad to be 4 feet, 8 ½ inches.
- Choose standards early in the project.

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ROBOTIC ARM

JOINT POSITION SENSORS

↓

ARM CONTROL COMPUTER

ISS COMPUTER SYSTEM

COMMAND AND CONTROL

↓

GUIDANCE, NAVIGATION, & CONTROL

CMG GIMBAL AND ROTATION SPEED COMMANDS

CONTROL MOMENT GYRO SIMULATOR

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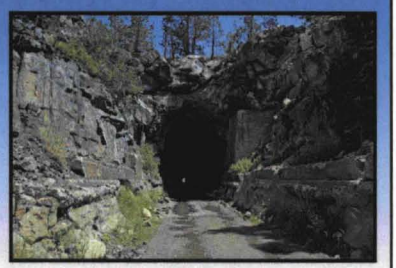
New Technology in 1866

- April 3rd – The Steamship *European* explodes in a huge fireball, along with about 400 feet of the Panama Railroad pier, while being unloaded on the Caribbean shore.
- April 16th – A crate leaking an "oily substance" explodes at the Wells Fargo office in San Francisco while being chiseled open for inspection.
- The California builders of the Transcontinental Railroad had discovered that Alfred Nobel's patented explosive, nitroglycerine, was 8 times more powerful than black powder and had been experimenting with it.
- California banned the transport of nitroglycerine in the state.



The Golden Spike
May 10, 1869

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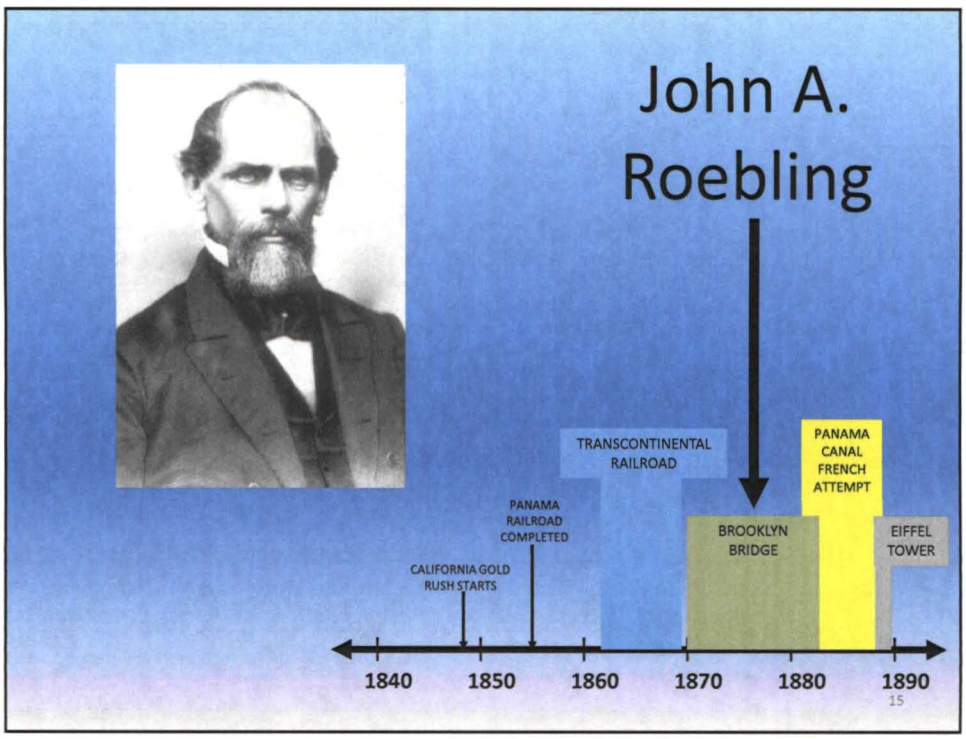

John A. Roebling

- Educated at Polytechnic Institute in Berlin in architecture, bridge construction, and hydraulics. Immigrated to the USA in 1831 at the age of 24.
- Worked as a civil engineer in the Midwest before pioneering a business making high quality iron cable.
- Designed and built a number of suspension bridges
- Developed the technology for the winding of stranded large diameter suspension cables from small diameter iron wire.
- Started design of the Brooklyn Bridge in 1867. His son Washington Roebling, also an engineer, worked with him on the design and construction planning.
- John A. Roebling died of tetanus contracted during surgery on July 22, 1869.

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Washington Roebling

- Studied engineering in Europe.
- Familiar with his father's suspension bridge design techniques, including the in-place fabrication of stranded iron wire suspension cables.
- Well respected as an engineer and supervisor by others working on the bridge survey and design.
- Took over management of the project after his father's death.

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The Design

- 276 foot tall towers would be built on each side of the East River to support the massive suspension cables.
- Foundations for the 2 towers would be 168 foot long, 102 foot wide, 3000 ton caissons built of wood and launched at a local shipyard.
- Layers of stone would be built up on top of the caissons to form the towers.
- The riverbed would be excavated by workers in the caisson.
- Once the excavation was completed such that the sides of the caisson were resting on the bedrock, the caissons would be filled with concrete resulting in a stable, permanent foundation for the towers.

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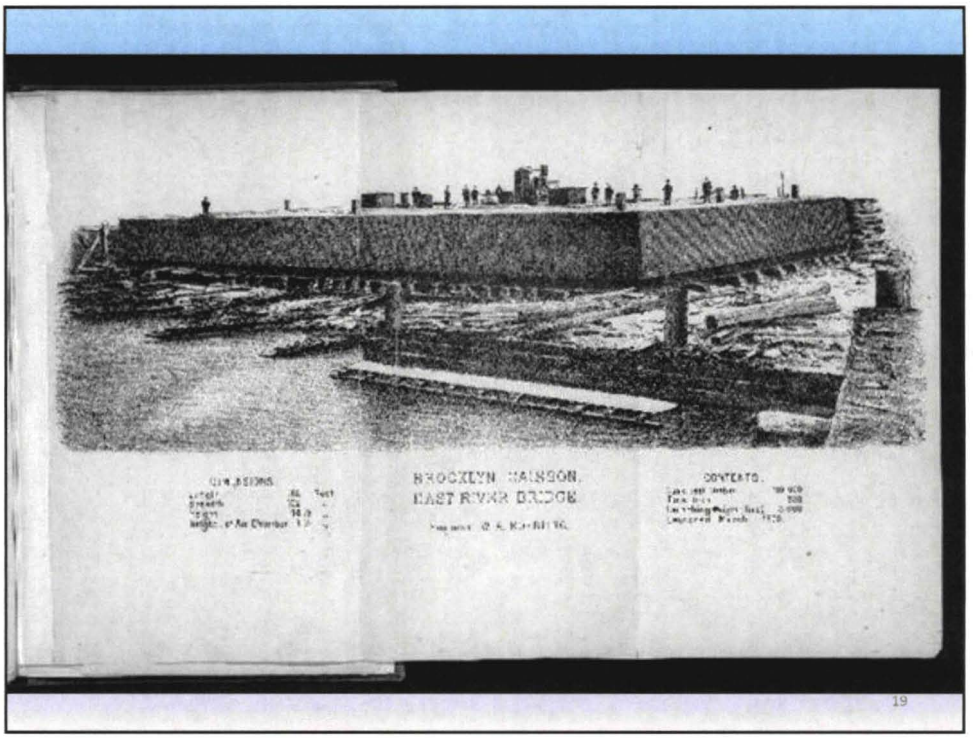

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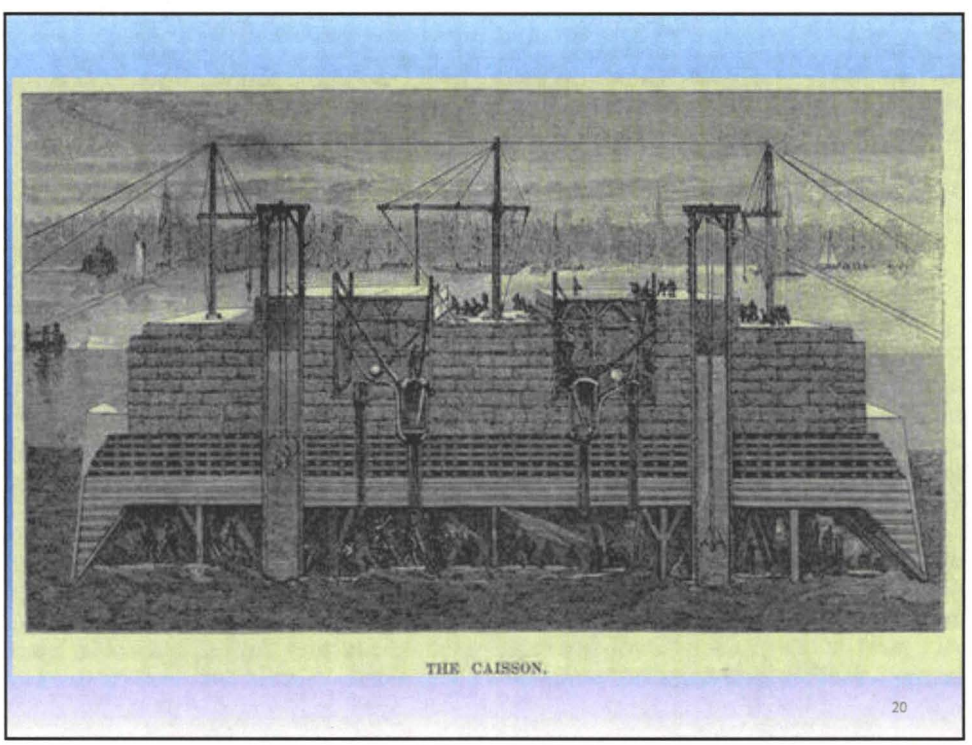

THE CAISSON.

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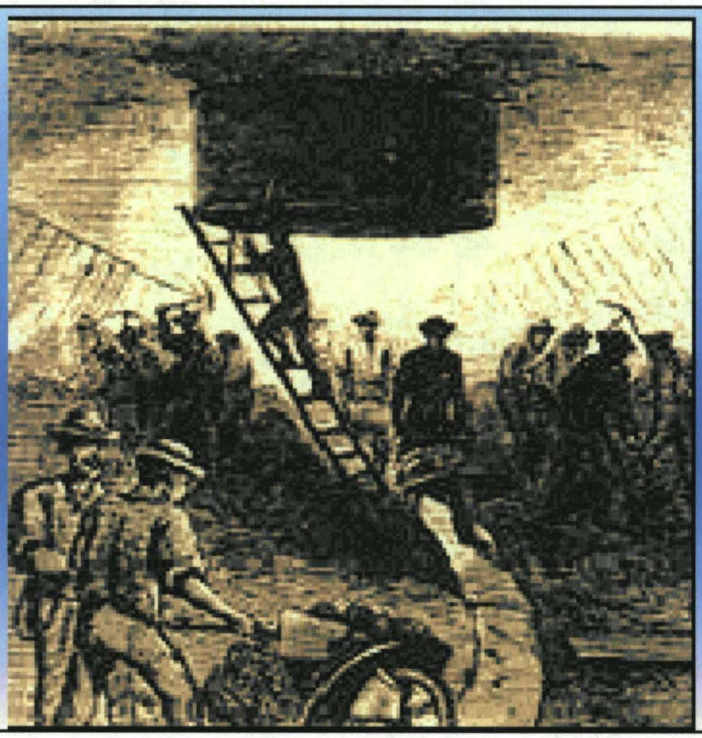

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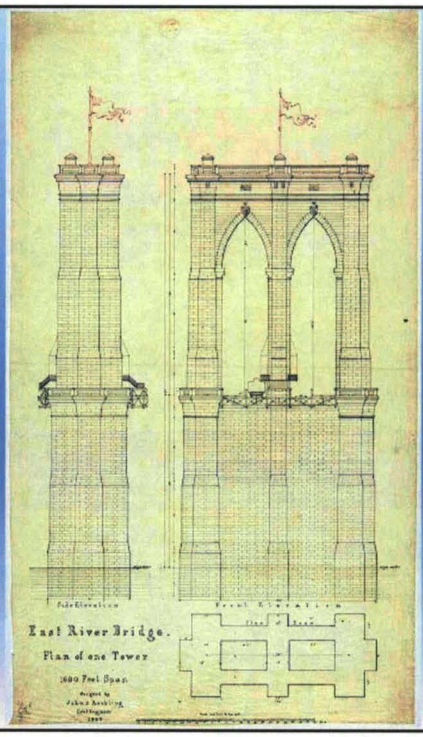

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Pressurized Caissons

- Technology first used in France in 1831.
- Washington Roebling had been schooled in this technique while studying in Europe.
- Technique was already in use in the construction of a bridge in St. Louis.
- Whether or not a man suffered from "caisson sickness", known today as the "bends", was considered a matter of luck.

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Roebling and Caisson Sickness

- As bridge construction progressed, Washington Roebling, making numerous trips into and out of the Brooklyn Bridge caissons, became stricken with caisson sickness and was confined to his residence.
- His wife Emily, became his contact with the construction managers as the bridge building progressed.
- Sometimes what you don't know can hurt you.

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Use of Fiber Optic Wiring on the ISS

- Fiber optic cabling was specified for use early in the ISS design process for audio, video, and communications.
- Lighter than copper
- Minimal EMI issues
- Well developed technology, except . . . Little or no experience in human spaceflight applications.

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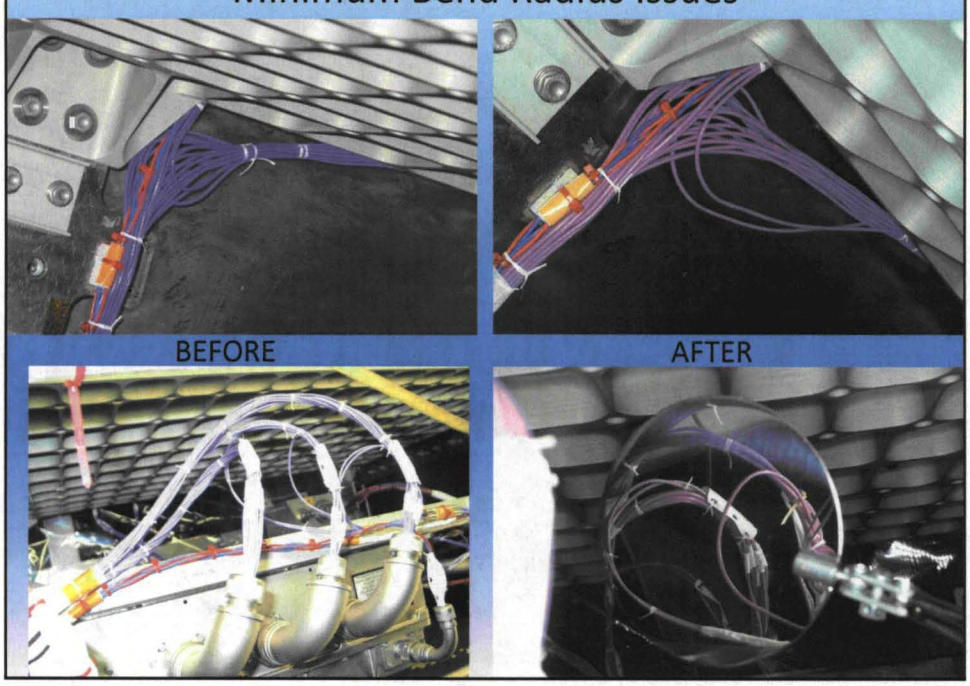
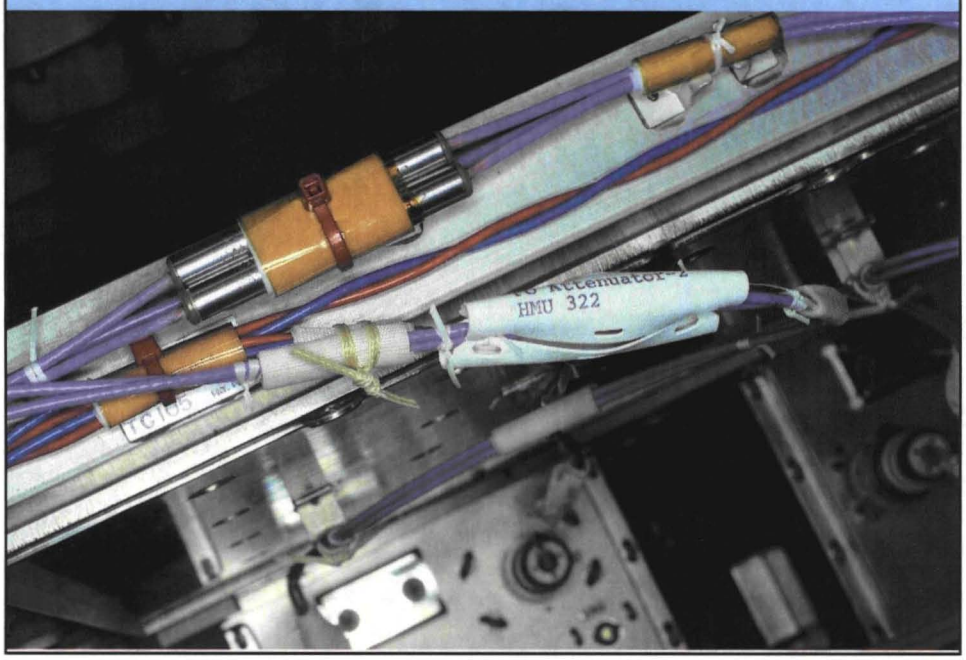
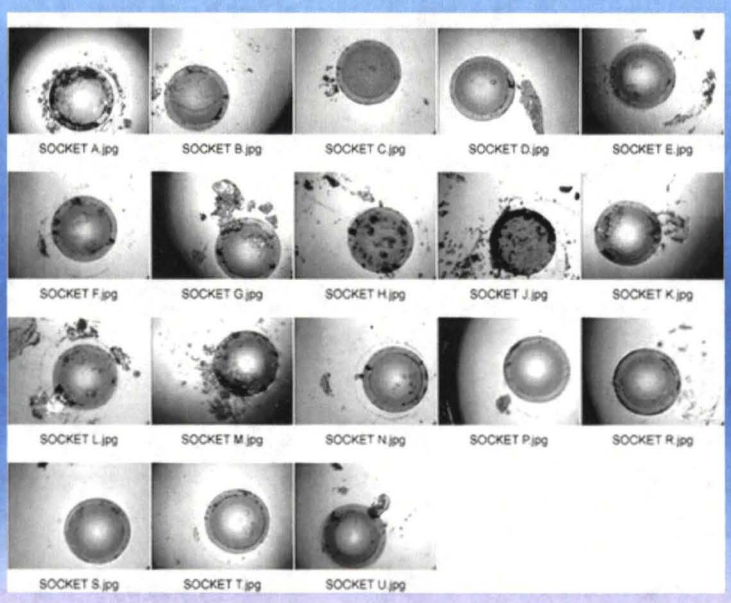
Minimum Bend Radius Issues



Securing of Fiber Optic Wiring Harnesses



Polishing and Cleaning of Connection Interfaces



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The Brooklyn Bridge and South Street Seaport in 1900. (Photo by Library of Congress, Prints and Photographs Division, Detroit Publishing Company Collection, LC-D4-90107.)

The Brooklyn Bridge opened on May 24, 1883

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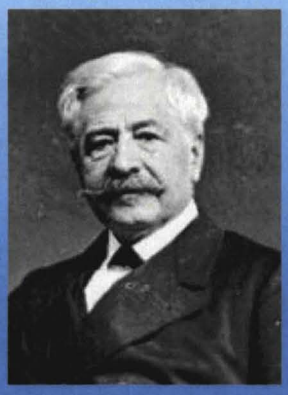
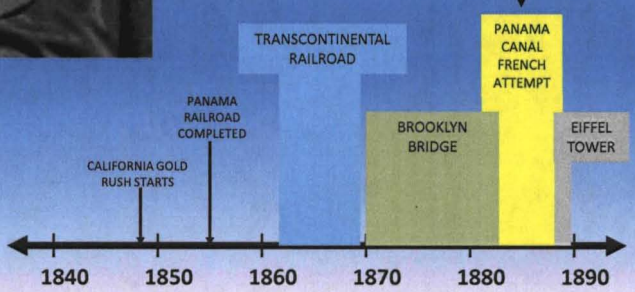
Ferdinand De Lesseps





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Ferdinand De Lesseps

- Successful Initiator and Leader of the French and Egyptian partnership to build the Suez Canal (Completed in 1869).
- Considered a National Hero in France.
  - Well respected by stockholders as President of the Suez Canal Company.
- Not technically inclined, but a diplomat, convincing speaker, and a persistent leader.
- Proposed a number of unfeasible engineering projects following his success with the Suez Canal.

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The 1879 International Interoceanic Canal Congress in Paris

- Organized by De Lesseps
- Purpose was to determine:
  - Location of the canal (14 were considered)
  - Type of canal (sea level or locks)
  - Cost
- After much debate, De Lesseps made a grandiose speech, convincing the delegates that a sea level canal at Panama was the best option.

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The Rejected Proposal

- On the afternoon of the same day as De Lesseps speech, Baron Godin de Lepinay, a Chief Engineer with the French Department of Bridges and Highways, presented a proposal for a canal with locks.
  - Explained how ships would be moved through a series of locks up and then back down over the higher terrain of the Isthmus of Panama
  - Proposed dams that would form 2 lakes to be used as part of the canal path to reduce the amount of excavation required.

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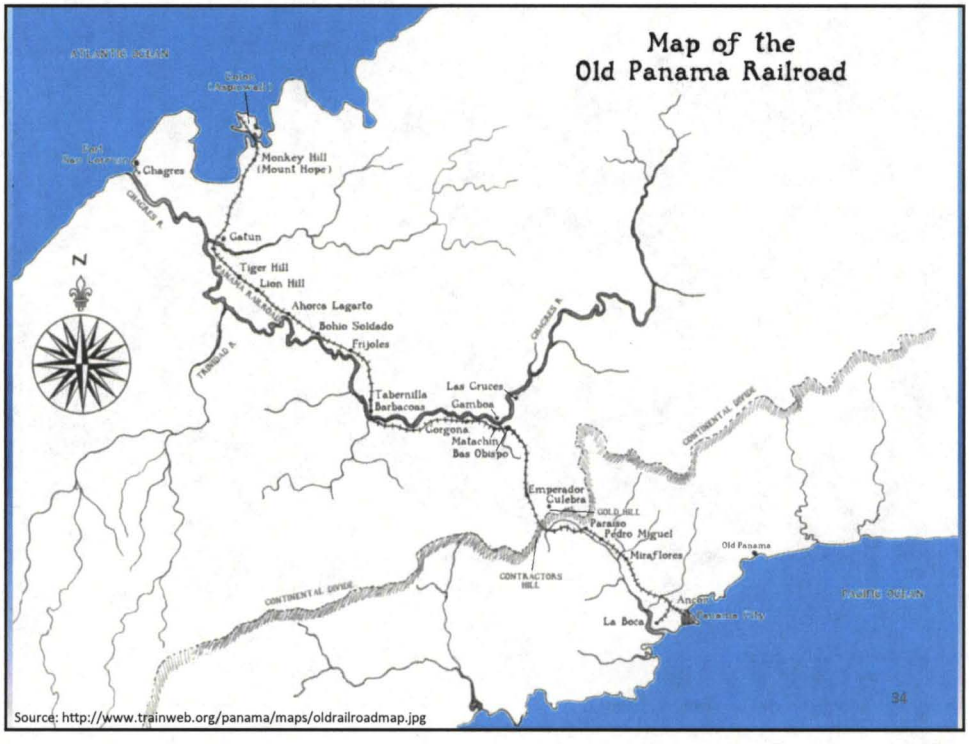

Source: http://www.trainweb.org/panama/maps/oldrailroadmap.jpg

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Decision Made

- At the end of the 2 week congress, delegates approved by vote a proposed sea level canal to be built at Panama:
  - Of the 74 that voted to approve the proposal, 19 were engineers, only 1 of which had actually been to Panama.
  - None of the 5 engineers present from the French Society of Engineers voted to approve the proposal.

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A Failed Attempt

- Construction started in early 1881.
- After it became clear a sea level canal was not possible, the French effort was modified to be a lock canal in 1887 and ended in bankruptcy 1889.
  - Cost $287 Million
  - Estimated that over 20,000 workers died
- However, much progress had been made that would ultimately lead to the success of the American effort.
  - Land already acquired from Columbia
  - Maps and surveys completed
  - Support infrastructure in place (hospitals, living quarters, warehouses, offices, etc.)
  - 65 Million cubic yards of excavation completed

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Why Failure?

- Lack of understanding of the harshness of the jungle environment.
- The amount of excavation required for a sea level canal was badly underestimated.
- Primary Cause: De Lesseps vision of a sea level canal was not possible and was therefore doomed to failure.
  - De Lesseps:
    - Ignored technical issues that were presented
    - Failed to consider differences between the terrain at Suez and the terrain at Panama
    - Ignored recommendations of more knowledgeable delegates if he disagreed with their views
    - Had blind faith that any obstacles could be overcome by determination
- De Lesseps used his reputation, fame, success at Suez, and ability to inspire to convince others that a sea level canal was the best option.

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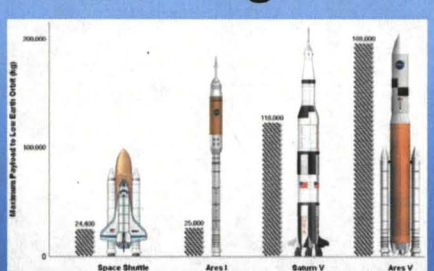
NASA Constellation Program

- Elements in Design
  - ARES 1 – LEO Rocket
  - Orion Crew Vehicle



- Cancelled in 2010
  - Schedule Delays
    - First launch had slipped from 2012 to 2014
  - High estimated Cost per flight

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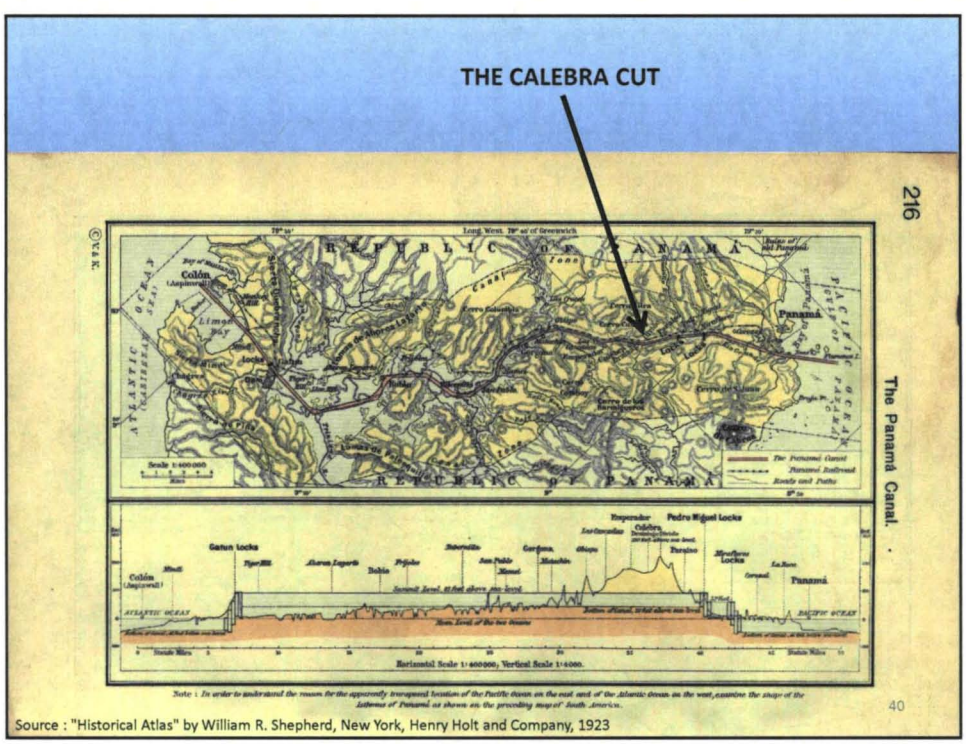
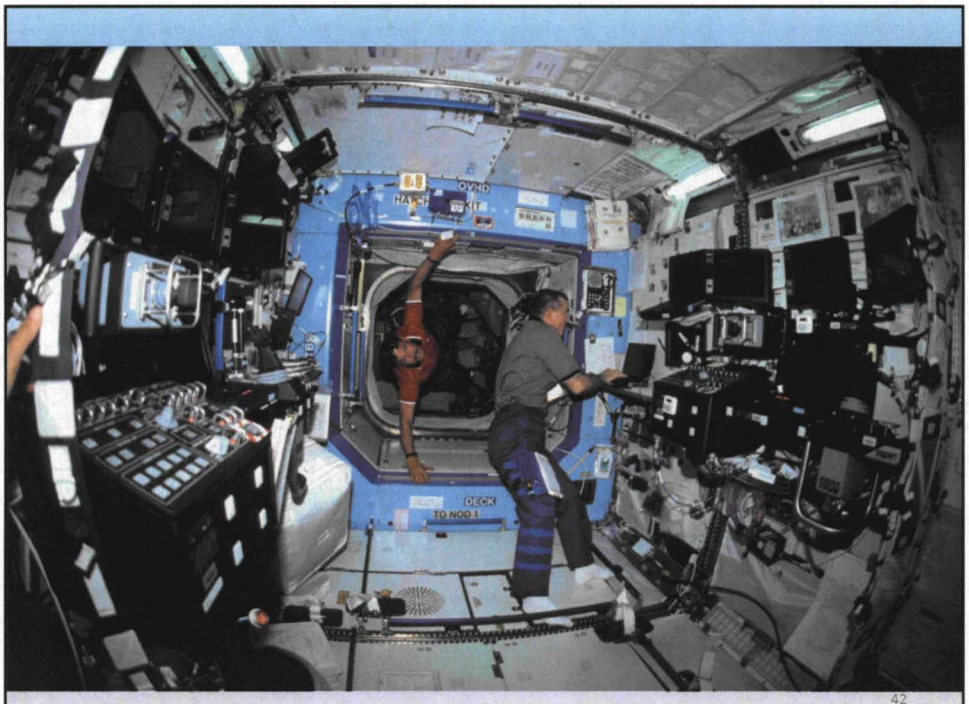


Source : "Historical Atlas" by William R. Shepherd, New York, Henry Holt and Company, 1923

Calebra Cut

- French Excavation: 19 Million cubic yards
- American Excavation: 96 Million cubic yards
- Even today, the angle of repose has never been accomplished in the Calebra Cut

No matter how good a Project Manager you may be, sometimes you are going to run into a problem that just can't be fixed!



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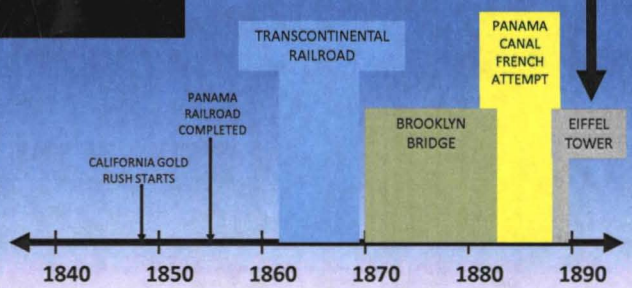
Gustave Eiffel



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Gustave Eiffel

- Started work as an engineer designing building iron bridges for a railroad company.
- Established his own company in 1867, eventually specializing in railroad bridges and viaducts.

- Designed and built the interior skeleton for the Statue of Liberty.
- Well known for the design and building of aesthetically pleasing iron structures with strong wind resistance

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1889 Paris World's Fair

- Contest announced in early 1884 by the Fair Commission soliciting proposals for the "centerpiece" of the 1889 World's Fair in Paris.
- Eiffel proposed a 1000 foot tall iron tower in late 1884.
  - Existing tallest structure in the world was the 555 foot Washington Monument
- Proposal announced as winner on June 12, 1886

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Eiffel's Problems

- French government agreed to provide only about a third of the construction cost of $1M.
- Debate over location of the tower.
- Lawsuits attempting to block tower construction:
- Multiple delays in approval and issuing of a contract to proceed from the World's Fair Committee.

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The Letter

- Eiffel wrote a letter to a supporter on the Fair Committee on December 22, 1886 outlining the problems and expressing his frustration:

"Today I must tell you once again that the delays in concluding the contract are making for a very serious situation . . . The time is disappearing and I should have started building months ago . . . If this situation goes on, I have to give up all hope of succeeding . . . Still, I remain ready to start work immediately . . . But, if I have not started work during the first part of January, I cannot possibly be finished in time. If we don't come to a definite agreement by December 31 . . . I will find it painful but necessary to give up my responsibility and take back my proposals. I would be very sorry renounce the construction of what most agree will be one the Exposition's principle attractions."

Source: Jonnes, Jill. *Eiffel's Tower*, page 25.

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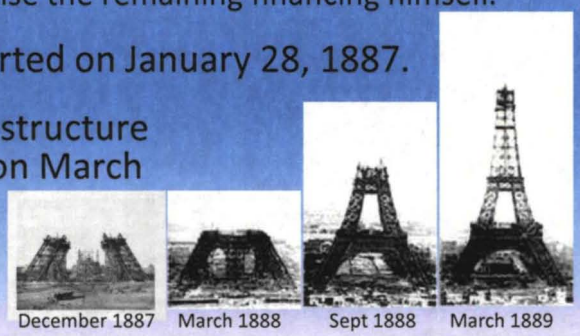
Change of Heart

- Eiffel put the letter in a drawer and never mailed it! Instead, he contacted the Fair Committee:
  - He offered to accept all liability in the event of a tower collapse.
  - He agreed to raise the remaining financing himself.
- Construction started on January 28, 1887.
- The Eiffel Tower structure was completed on March 31, 1889.



December 1887 March 1888 Sept 1888 March 1889

Why the Change?

- In the course of writing the letter, Eiffel listed the issues and discovered that there were only two real problems:
  - Liability
  - Financing
- He believed in the tower enough to risk his own personal fortune.
- As an engineer, he knew that the tower would not collapse.
- As a businessman, he knew the tower would be so popular that it would ultimately be wildly profitable.
- Thus, solutions were found by taking some time to reflect and think before he hit "SEND".

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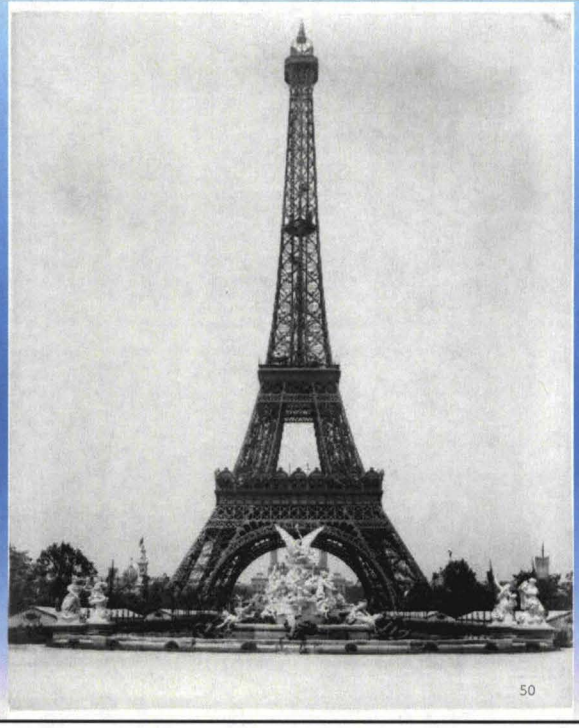
Workers assembled 18,000 pieces of iron in just 21 months, under budget and in time for the fair's opening day. The tower was paid off in the first year of operation



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Successful Project Managers

- Assemble a team with the knowledge and experience needed to complete the project.
- Identify possible major issues as early as possible.
- Make sure a "watch list" of project issues is created and regularly reviewed.
- Provide sufficient resources for addressing issues.
- Listen to recommendations from all levels of the project team.

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Successful Project Managers

- Make sure new technology is understood before implementation.
- Don't include ego as determining factor when making decisions.
- Understand and maintain a good working relationship with those supporting the project.
- Mentor successors.
- Are timely when identifying the need the restructure a project.

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Sources

1. Bain, David Haward. *Empire Express: Building the First Transcontinental Railroad*. Penguin Group, 1999.
2. McCullough, David. *The Great Bridge*. Simon and Schuster, 1972.
3. McCullough, David. *The Path Between the Seas: The Creation of the Panama Canal, 1870 – 1914.* Simon and Schuster, 1977.
4. Jonnes, Jill. *Eiffel's Tower*. Penguin Group, 2009.

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Recommended Reading

1. "Longitude" by Dava Sobel
2. "Crystal Fire" by Michael Riordan and Lillian Hodeson
3. "$E=mc^2$" by David Bodanis
4. "Hoover Dam" by Joseph E. Stevens
5. "Absolute Zero and the Conquest of Cold" by Tom Shachtman
6. "Empires of Light" by Jill Jonnes
7. "Conquering Gotham: Building Penn Station and Its Tunnels" by Jill Jonnes

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