

Nikola Tesla and the Tesla Science Center

November 9, 2017

Power Electronics Symposium

PELS IEEE

Neil Baggett



Who was Nikola Tesla?



Nikola Tesla

- Inventor
 - Electrical Engineer
 - Mechanical Engineer
 - Physicist
 - Wizard
-
- Serbian
 - Croatian
 - American
 - World citizen



What did Tesla do?

- 1888: Invented induction motor.
- 1890: Invented neon, phosphorescent lights.
- 1891-93: Helped invent radio.
- 1899: Invented remote control (for a boat).
- 1894: Studied x-rays.
- 1913: Designed bladeless turbine.
→ Flow meter, speedometer, odometer
- 1899–1917: Studied global energy transmission.

What Was Tesla Like?

- 6' 4" 142 lb. ± 1 Elegantly attired.
- No earned academic degrees (12 honorary).
- Spoke eight languages; memorized books.
- Hated jewelry, touching hair, shaking hands.
- Liked numbers divisible by 3.
- Worked long hours, slept 2-3 hours.
- Walked 8-10 miles every day.
- Dinner 8-10 PM, back to the lab until 3 AM.
- Visualized a design in detail, then drew it.



Tesla's Birthplace: Smiljan, Croatia



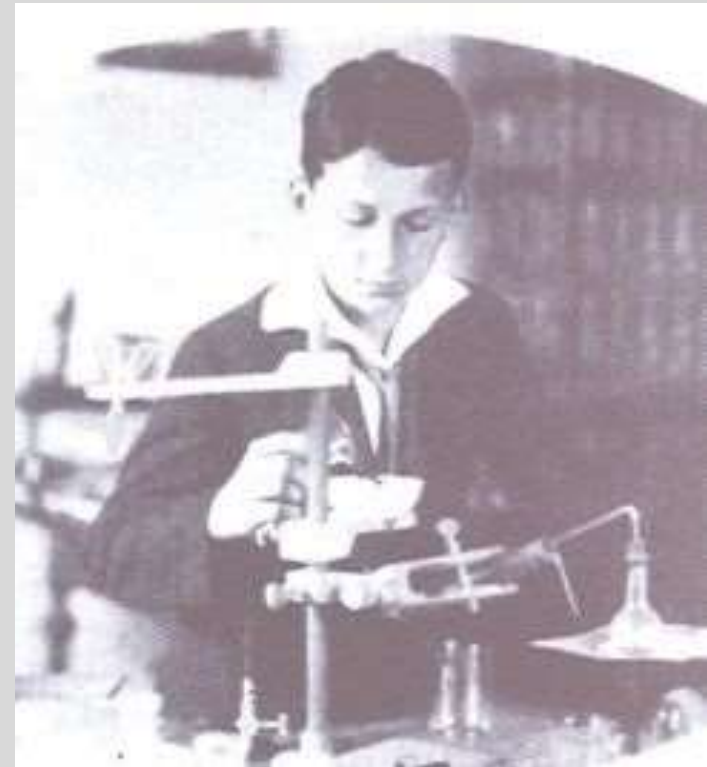
Milutin Tesla



Djuka Tesla

Early Life

- 1856: Serbian parents.
Born in Smiljan, Croatia.
- Brilliant student. Educated father, inventive mother.
- Nikola wanted to invent, too.



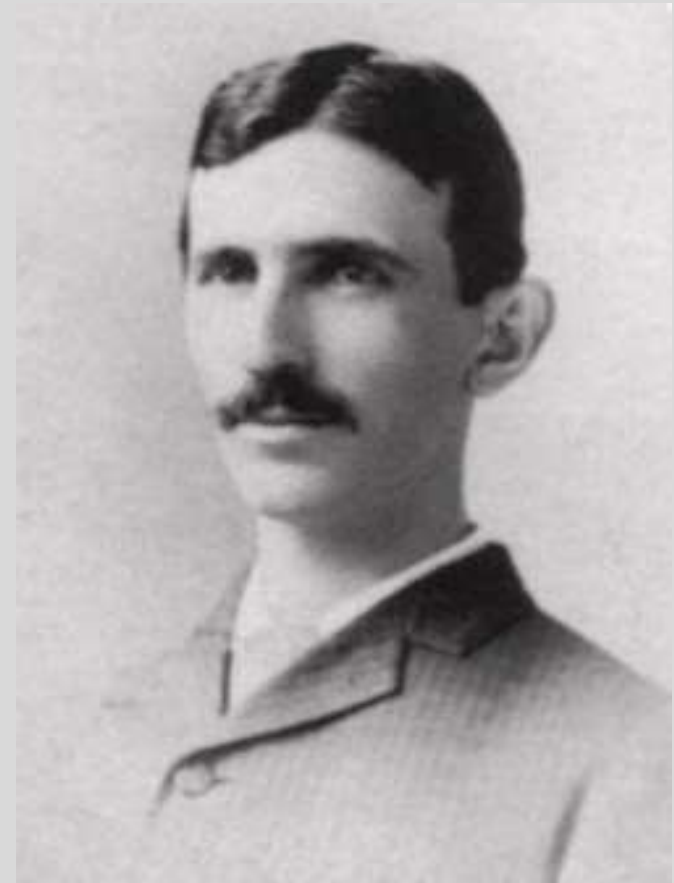
Tesla as a Young Man

- 1875: Joanneum Polytechnic School, Graz, Austria
- 1876: Prof. Pöschl:
A motor must have brushes.
- 1880: Karl-Ferdinand University, Prague
- 1882: polyphase induction motor (AC motor)



Tesla Moves to America

- 1882: Worked for Edison Continental Lighting in Paris.
- 1884: At 28, he was invited to NY to work directly for Thomas Edison.



United States in 1884

- President: Chester Arthur
- 38 states
- Population: 55 million
1900: 76 million
1920: 106 million
- Washington Monument - nearly finished
- *Huckleberry Finn*, by Mark Twain - published

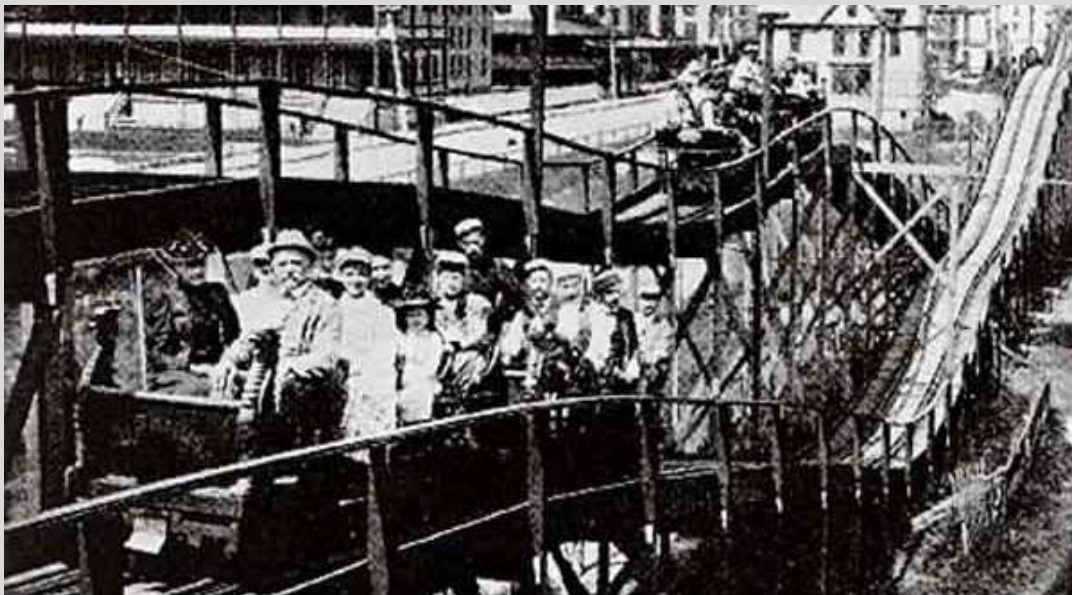


New York City in 1884



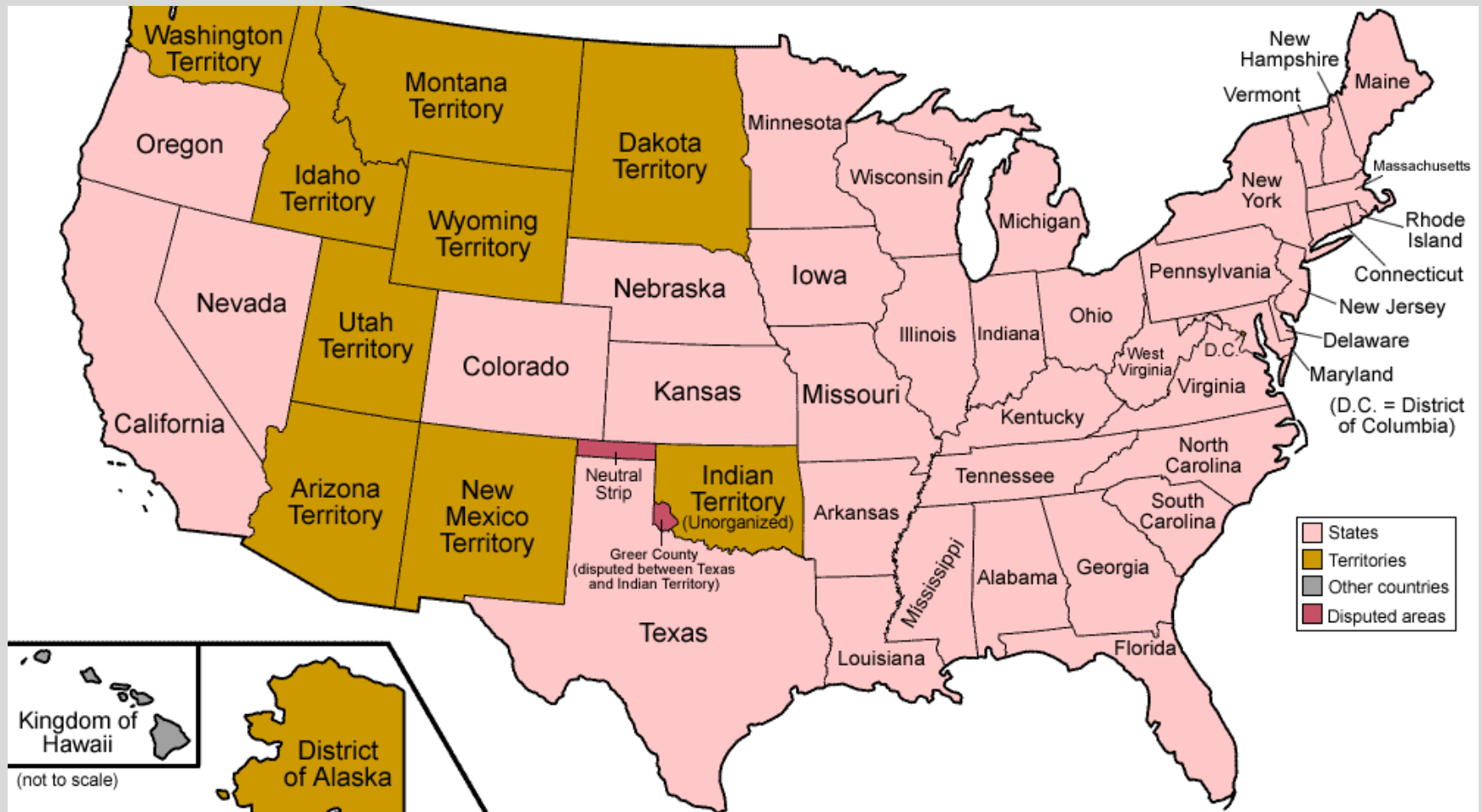
New York City - FAQ

- 1880: Population: 1.2 million
- 1882: Electric lights (DC power)
- 1883: Brooklyn Bridge
- 1884: First roller coaster -- Coney Island



On the Gravity Pleasure Switchback Railway, you ride along a wavy hill at an invigorating six mph.

United States in 1884



Yankee Ingenuity

- *Americans are more Addicted to Practical rather than Theoretical Science.*
--- Alexis de Tocqueville 1840
- No time for theory – we're in a hurry!
- 1803-1890: Expanding westward (2,700 miles)
- 1840-1900: 682,000 U.S. patents
- Yankee ingenuity – trial and error
- But Tesla took time for theory.

19th Century Physics

- 1823 Ampere's law AC power
- 1831 Faraday's law AC power
- 1873 Maxwell's equations → EM waves
- 1887 EM waves – Hertz Radio ...

---- Electricity is the physics frontier. ----

- 1895 X-rays – Roentgen (& Tesla) Images
- 1896 Radioactivity – Becquerel Uranium
- 1897 Electron – Thomson First lepton

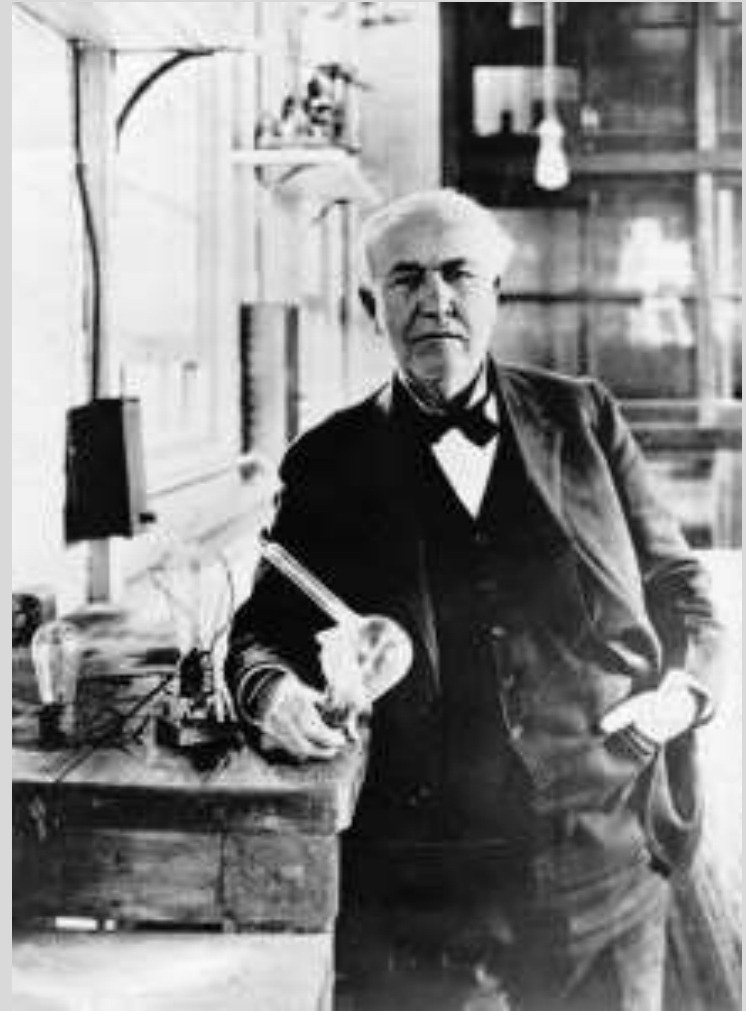
19th Century Inventions (E&M)

- 1837 Telegraph Morse
- 1876 Telephone Bell
- 1878 Phonograph Edison
- 1879 Electric lights Edison
- 1882 Electric power DC – Edison

---- Lighting is an industrial frontier. ----

- 1888 Induction motor AC – Tesla
- 1895 AC power grid Tesla, Westinghouse

1884 Tesla and Edison



June: Tesla started work for Thomas Edison.
December: He quit.

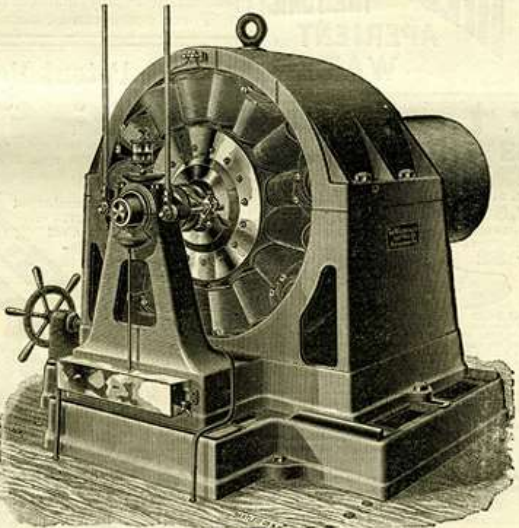
The AC Motor

- In late 1884, Benjamin Vail and Robert Lane hired Tesla to build an arc lighting system in Rahway, New Jersey. Then they dropped him; by 1886, he was digging ditches.
- Charles Peck and Alfred Brown met Tesla and decided to support his work on the AC motor (induction motor).
- April 1887: Tesla Electric Company on Liberty Street. Finally, Tesla could develop his 1882 AC motor idea.
- By May 1888, the company had obtained 40 patents on 1, 2, and 3 phase AC motors and related equipment.

Tesla Becomes Famous

- On May 16, 1888, Tesla presented a lecture to the American Institute of Electrical Engineers (AIEE):
A New System of Alternate Current Motors and Transformers.
- This made Tesla a leading “electrician.”
- July 7, 1888, George Westinghouse bought all 40 patents from Tesla Electric Company.
- Cash plus a royalty: \$2.50 per horsepower per motor
- Ditches to riches in two years: 1886 - 1888

Tesla and Westinghouse



**THE
ALTERNATING
SYSTEM.**

Incandescent Electric Lighting from Central Stations made Universal, Economical, and Profitable, irrespective of distance.

The Westinghouse Electric Co.,
PITTSBURGH, PA.
Eastern Office, 17 CORTLANDT STREET, NEW YORK.

After selling Westinghouse his AC patents, Tesla worked with him in Pittsburgh for a year.

In 1889 he returned to New York and worked on high frequency and wireless.



**PERFECT
PARTNERSHIP**

George Westinghouse and Nikola Tesla, seeking to make long distance electric power transmission a reality, they combined their skills, their genius and their belief in a new technology... alternating current. Together they started a revolution that electrified the world. A Perfect Partnership.

1891 Ames Power Plant

- In 1891, Westinghouse installed an AC power plant in Ames, Colorado, using Tesla's patents. One of the first hydroelectric AC power plants, it powered a stamp mill at the Gold King Mine.
- First commercial system to transmit AC power for a long distance (2.6 miles).
Still operating (new generator in 1904).

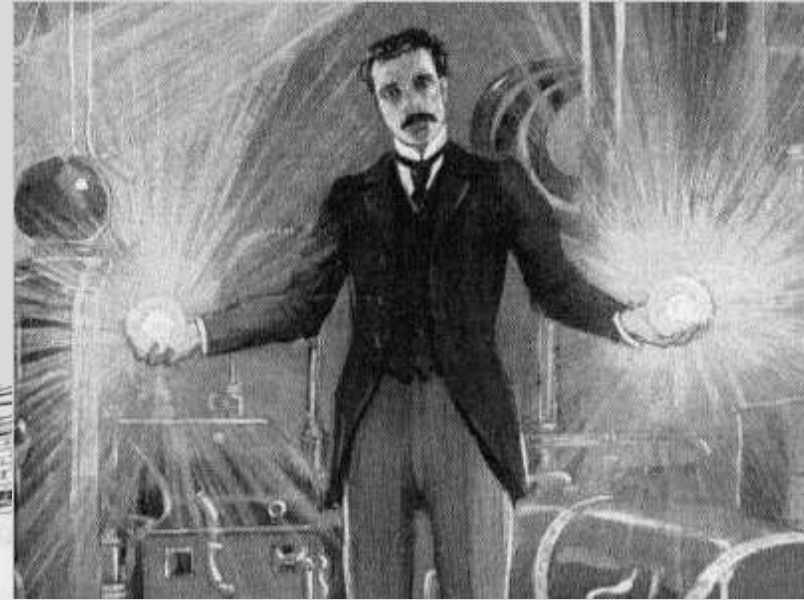
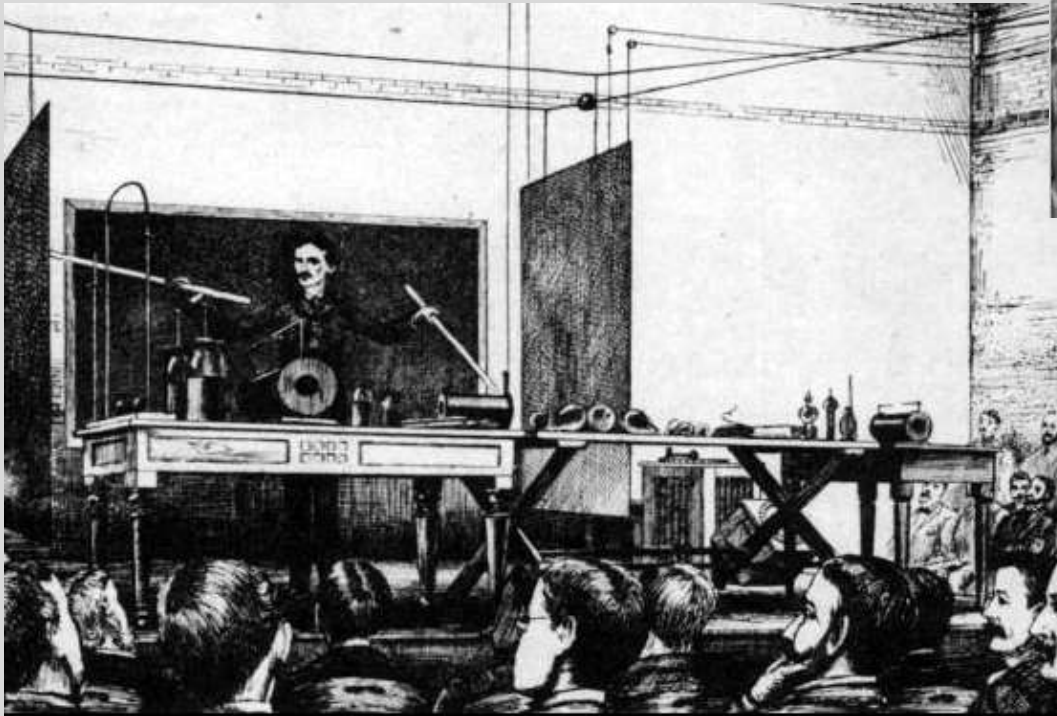
1890s A Busy Decade, Part 1

- 1889: In Paris, Tesla learned of “Hertzian waves.” (Electromagnetic waves: radio, light, ...)
- 1890: Invented oscillating transformer (**Tesla Coil**) to study Hertzian waves.
- 1890: Invented low pressure tube lamps.
- 1891: Tesla canceled \$2.50/hp royalties due from Westinghouse for 1988 AC motor patent.
- 1891: Tesla became an American citizen.

1891 Columbia Lecture

High Frequency Phenomena

In 1891, it's all about lighting.
Electrician or magician? →



← Wireless lamps light up anywhere between high voltage plates.

1892 European Lectures

High Frequency

- February 3: *Institution of Electrical Engineers* London
- February 4 : *Royal Institution* London
- February 19: *Société Française de Physique* Paris

Wireless power for lamps ... and motors ...

“Motors might be operated at considerable distances.”

Electronic vacuum tubes – anticipated by 15 years.

1893 American Lectures - Wireless

- February 24: *Franklin Institute* Philadelphia
- March 1: *National Electric Light Association* St. Louis

Tesla said we could...

“...disturb by means of powerful machines the electrostatic condition of the earth, and thus **transmit intelligible signals** or perhaps **power**.”

Because “earth’s charge, when disturbed, oscillates...**points on the earth’s surface...will be disturbed.**”

Signals or **energy** could be withdrawn from those points.

[Stay tuned for Wardenclyffe.]

5

Current flowing within the receiver coil is converted into direct current (DC) by the receiver circuit, thus charging the battery of the device.

4

The magnetic field generates current within the receiver coil of the device

3

Alternating current flowing within the transmitter coil creates a magnetic field which extends to the receiver coil (when within a specified distance)

RECEIVER CIRCUIT

RECEIVER COIL

POWER BY
PROXI™

TRANSMITTER COIL

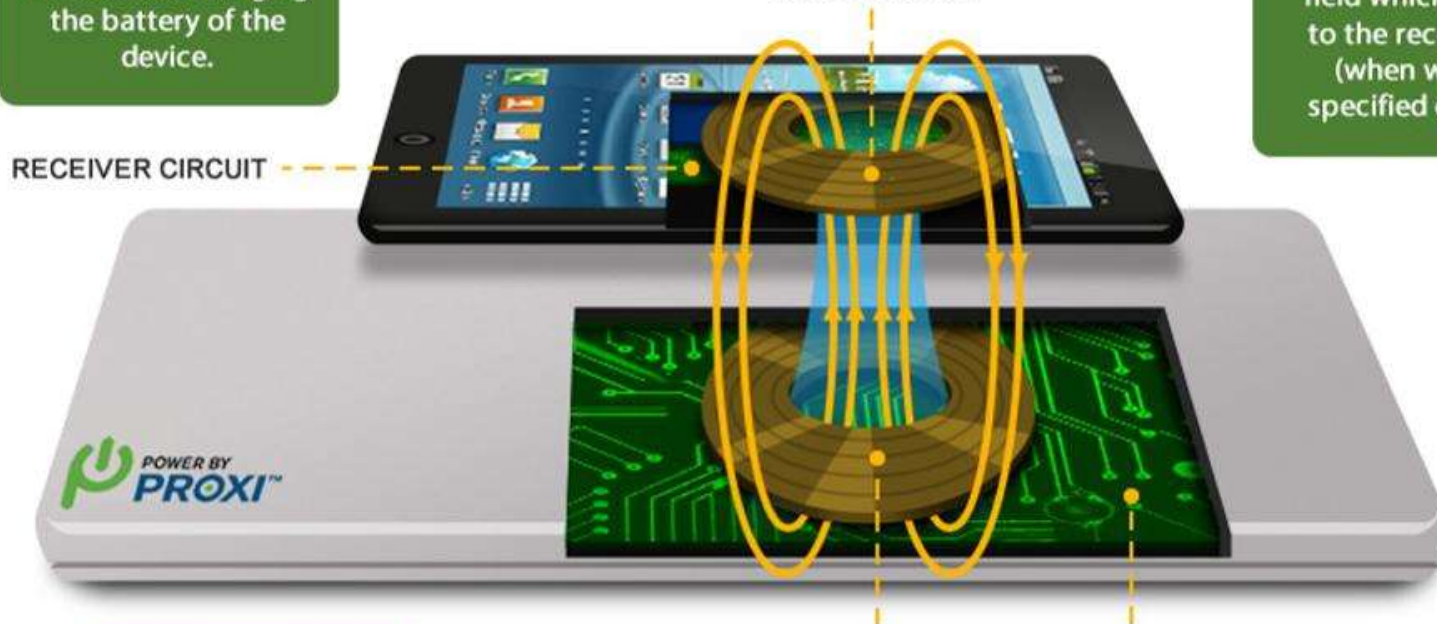
1

Mains voltage is converted into high frequency alternating current (AC)

2

The alternating current is sent to the transmitter coil by the transmitter circuit

TRANSMITTER CIRCUIT



1893 Columbian Exposition

- Westinghouse won the contract to light the 1893 Chicago World's Fair.
- 27 million visitors saw that AC power is safe.
- They also learned about:

| | |
|----------------------|-------------------|
| Moving sidewalks | Hershey bars |
| Books in Braille | Electric kitchens |
| Phosphorescent lamps | Ferris Wheels |



Columbian Exposition Lighting



1893 Niagara Falls Power Plant

- 1893: Westinghouse Electric selected to generate AC power at Niagara Falls.
- 1893: General Electric selected to transmit AC power 20 miles to Buffalo.
- 1895: Niagara Falls Plant began operations.
- 1896: Power reached 75 megawatts.
- United States **AC power grid** was born.



Niagara Falls Power Plant 1895

1890s A Busy Decade, Part 2

- 1894: Tesla used light from cathode ray tubes to make photographs. Unexposed plates stored in a corner had “unaccountable marks and defects.”
- 1895: On March 13, fire destroyed Tesla’s South 5th Avenue lab with all of his equipment and records.
- 1896: Tesla generated x-rays and studied them. He x-rayed his own head for 20 minutes. Hmm...
- 1898: Teleautomaton: Radio-controlled boat designed to send a torpedo to a battleship.

1899 Wireless Power for All

- Since 1893, Tesla had wanted to disturb the electrostatic condition of the earth and transmit signals or power.
- He dreamed of supplying power to the world. Maybe even free power.
- To disturb the earth, he would need more space than a lab in Manhattan.

Testing Wireless Transmission

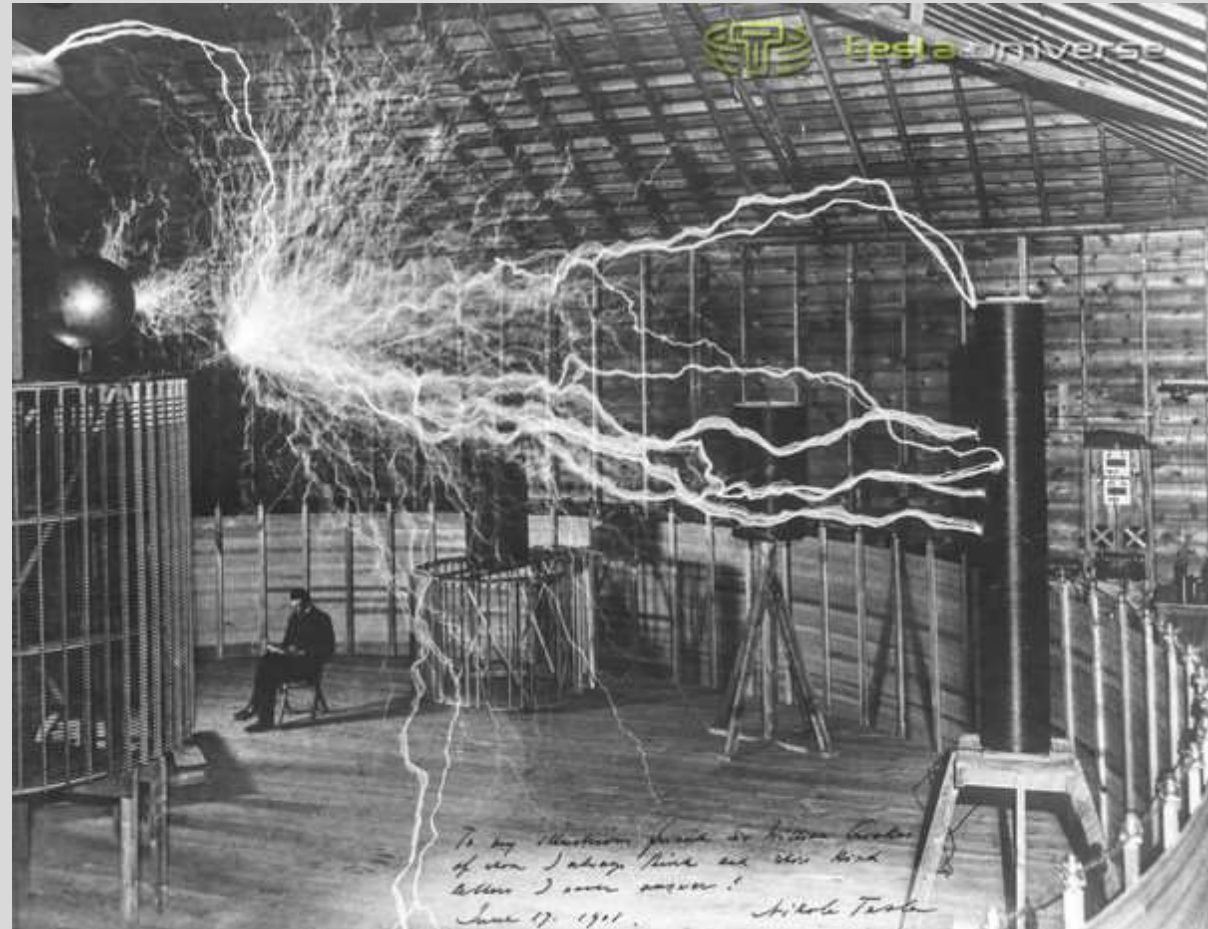
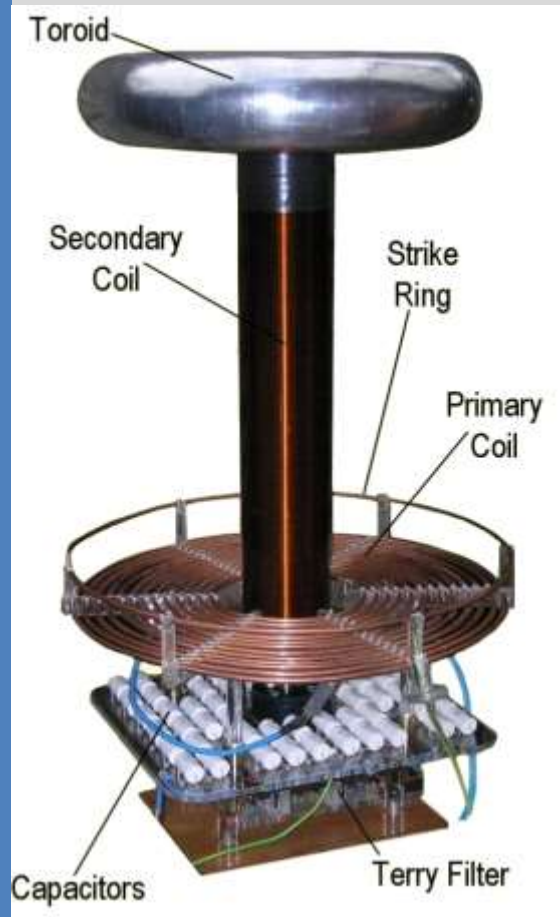
How about Pike's Peak?



Colorado Springs Experimental Station



The Colorado Experiment



The Colorado Experiment



1901 World Wireless System

- Now Tesla was ready to begin transmitting messages and energy around the world.
- In March 1901, J. P. Morgan agreed to provide \$150,000 for this project.
- In August, James Warden provided Tesla with 200 acres of land near the train station in Wardenclyffe (now Shoreham) on the north shore of Long Island.

[illegible]

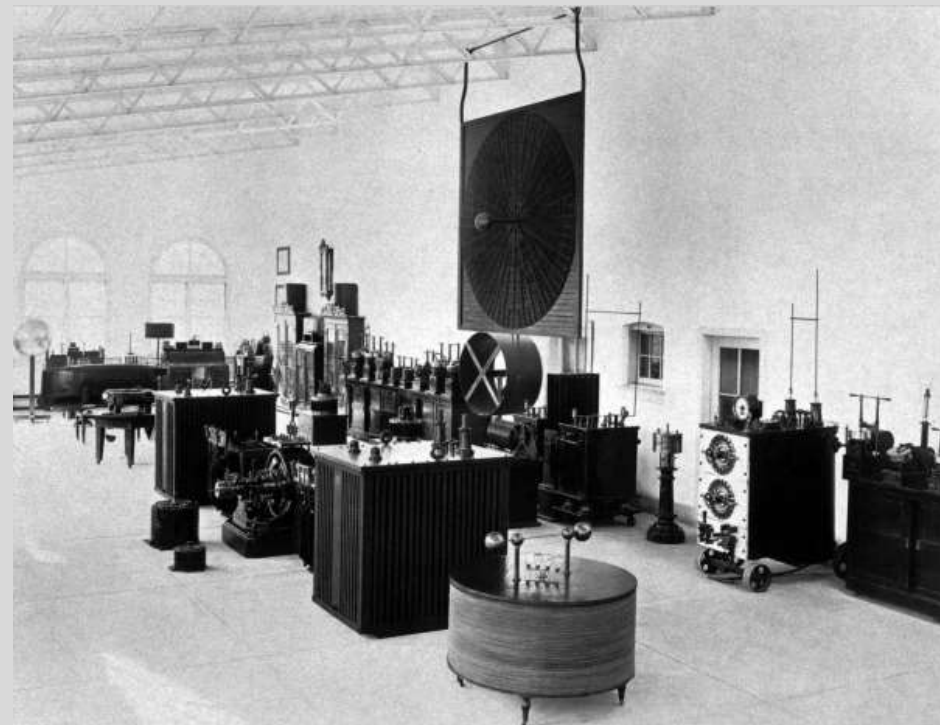
A map of the area around the University of North Carolina at Chapel Hill. The map shows a network of roads including H. Country Rd, Black Mt Rd, James St, James Ct, Miller Ave, and various other streets like Chapel Hill, North Carolina, and others. The map is oriented with North at the top.

The Wardenclyffe Laboratory



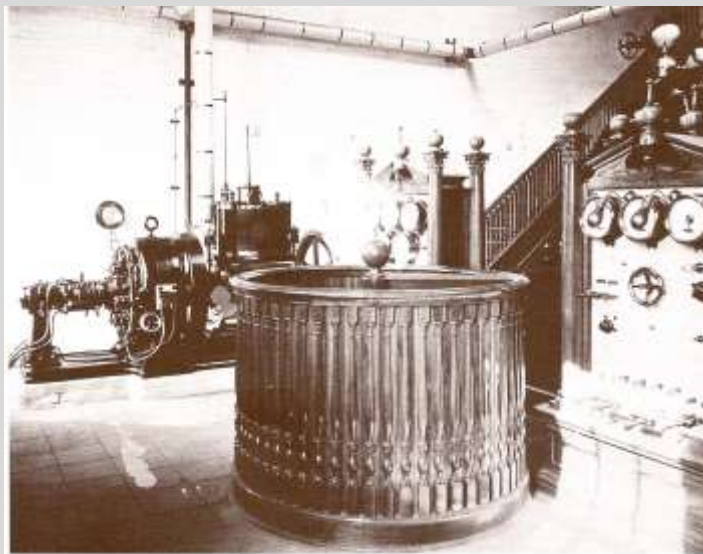


North side



South side

Wardenclyffe Laboratory Interior



How Would It Transmit?

- In the laboratory, Tesla would generate 44 kV at 1 - 200 kHz and charge four large capacitors. He would then deliver 200 kW of 4-phase power to the primary coil in the tower.
- The Tesla coil would produce a pulse of very high voltage (a few MV), and send it into the Earth through a grounding rod. He expected to set up a stationary current wave in the earth's crust at its resonant frequency, which he estimated at 6 Hz.

How Would It Receive?

- To receive messages or power, you would need a receiver—another Wardenclyffe tower? He decided it could be much smaller:
- With a ground wire and a small elevated terminal, he expected to receive enough power to illuminate fluorescent lamps.
- Or call Mom from Paris --- think cell phone.

Think Cell Phone

"When wireless is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole. We shall be able to *communicate with one another instantly, irrespective of distance*. Not only this, but through television and telephony we shall see and hear one another as perfectly *as though we were face to face*, despite intervening distances of thousands of miles; and the instruments through which we shall be able to do this will be amazingly simple compared with our present telephone. *A man will be able to carry one in his vest pocket.*"

-Nikola Tesla, 1926

Marconi

- On December 12 & 13, 1901, Guglielmo Marconi transmitted “SSS” across the Atlantic. **Radio was born.**
- In January 1902, Tesla wrote to J. P. Morgan, proposing a “World Telegraphy System,” transmitting news to individuals worldwide.
- Morgan was forming steamship and railroad trusts. He would not invest in this, but...

The End of Wardenclyffe

- Morgan did help Tesla to plan a new company, to be capitalized at \$10 million. But no one bought shares.
- In 1903, Morgan told Tesla no for the last time. Tesla switched on the tower, which emitted lightning bolts that were seen from Connecticut, 20 miles across the Sound.
- Tesla looked for other sponsors, spent his own money, and mortgaged his Wardenclyffe property, but it was not enough. In May 1905, his patents from 1888 expired; income stopped.
- He worked on other inventions, but never found a big success. The mortgaged land was foreclosed and the tower was sold for scrap in 1917.

Demolition of the Tesla Tower

July 1917

Heirs of George Boldt wanted to recover debts owed by Tesla.



Tesla's Final Years

- Tesla went back to Manhattan and spent his last years in the New Yorker Hotel.
- He continued to work on new ideas and often held a press conference on his birthday. His opinions were always interesting.
- He spent time in Bryant Park, and one special pigeon became his best friend.
- He died in 1943.

Peerless and Agfa

1939-2013



Tesla Science Center (and crowdfunding!)



We're trying to raise money to buy back Nikola Tesla's old laboratory, known as the Wardenclyffe Tower, and eventually turn it into a museum.

\$1,370,461 USD

raised by 33,253 backers in a month

161% funded

No time left

 **\$850,000** USD goal
Flexible Funding

CAMPAIGN CLOSED

This campaign ended on
September 30, 2012

CONTRIBUTE NOW

This campaign is currently unable to accept contributions. Tap the heart icon to follow this campaign and come back to it later.

Select a Perk

From August 15 - 24, 2012, over \$1 million was raised! That was over \$100,000 per day for nine days.

By the conclusion of the fundraising campaign, over 33,000 people from at least 108 countries around the world had contributed to saving Wardenclyffe. Contributions ranged from \$1 to \$35,000. The average contribution was about \$40.

May 3, 2013



On May 2, 2013, Tesla Science Center at Wardenclyffe bought the Wardenclyffe property. It was overgrown with weeds and vines and the buildings were deteriorating.



The Lab in 2013



Tesla Science Center



Shoreham, New York

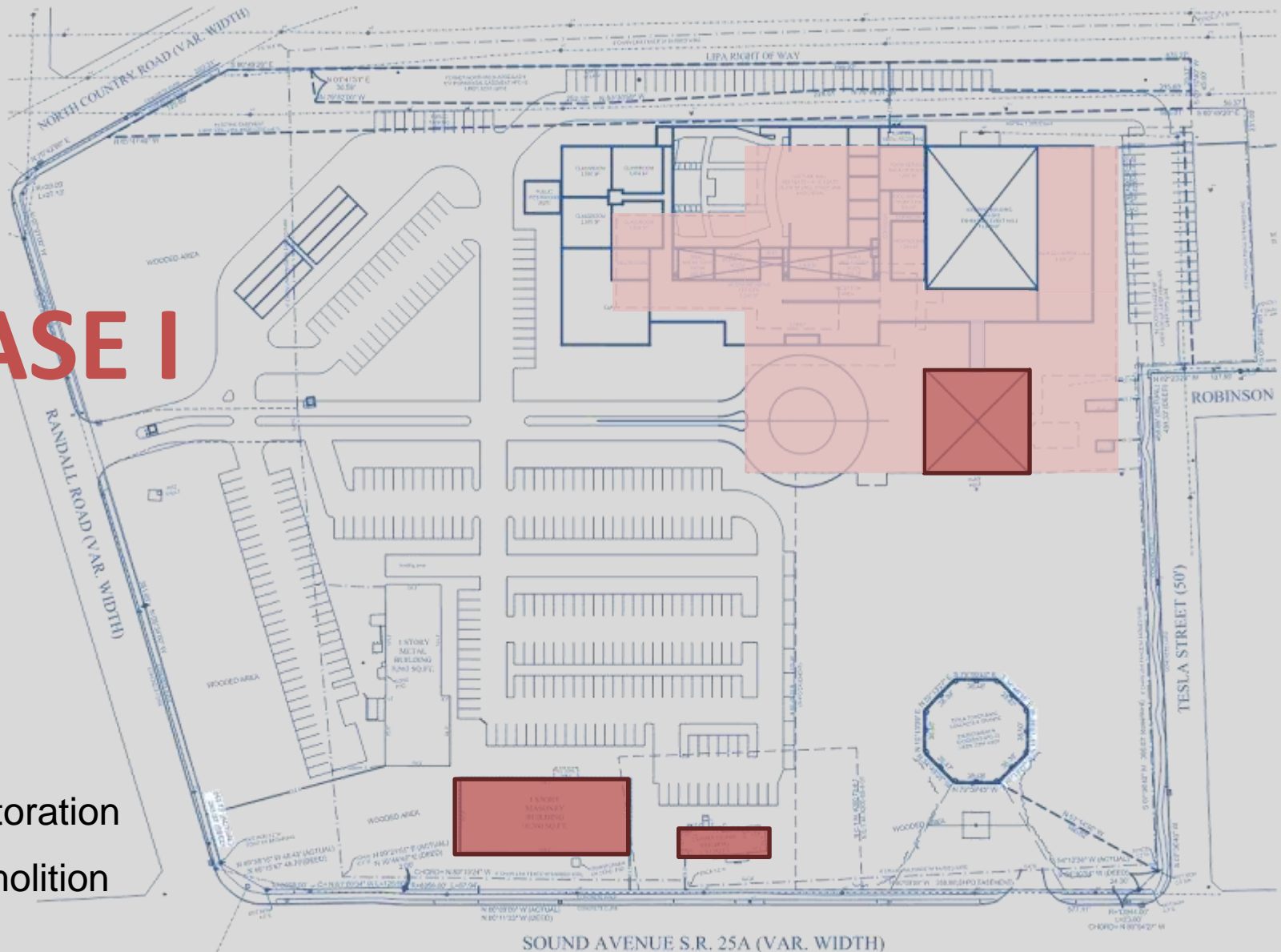
TSC Long Term Goals

- Restore Nikola Tesla's last laboratory to its condition in 1902.
- Create a **museum** in the laboratory that will inform people about Tesla, his inventions, and his impact on our lives.
- Create a **learning center** that will teach young people the importance of science, technology, and innovation.
- Create an **innovation center** for startup companies.
- Provide a **maker space** where people can build their inventions.

The Future Tesla Science Center

PHASE I

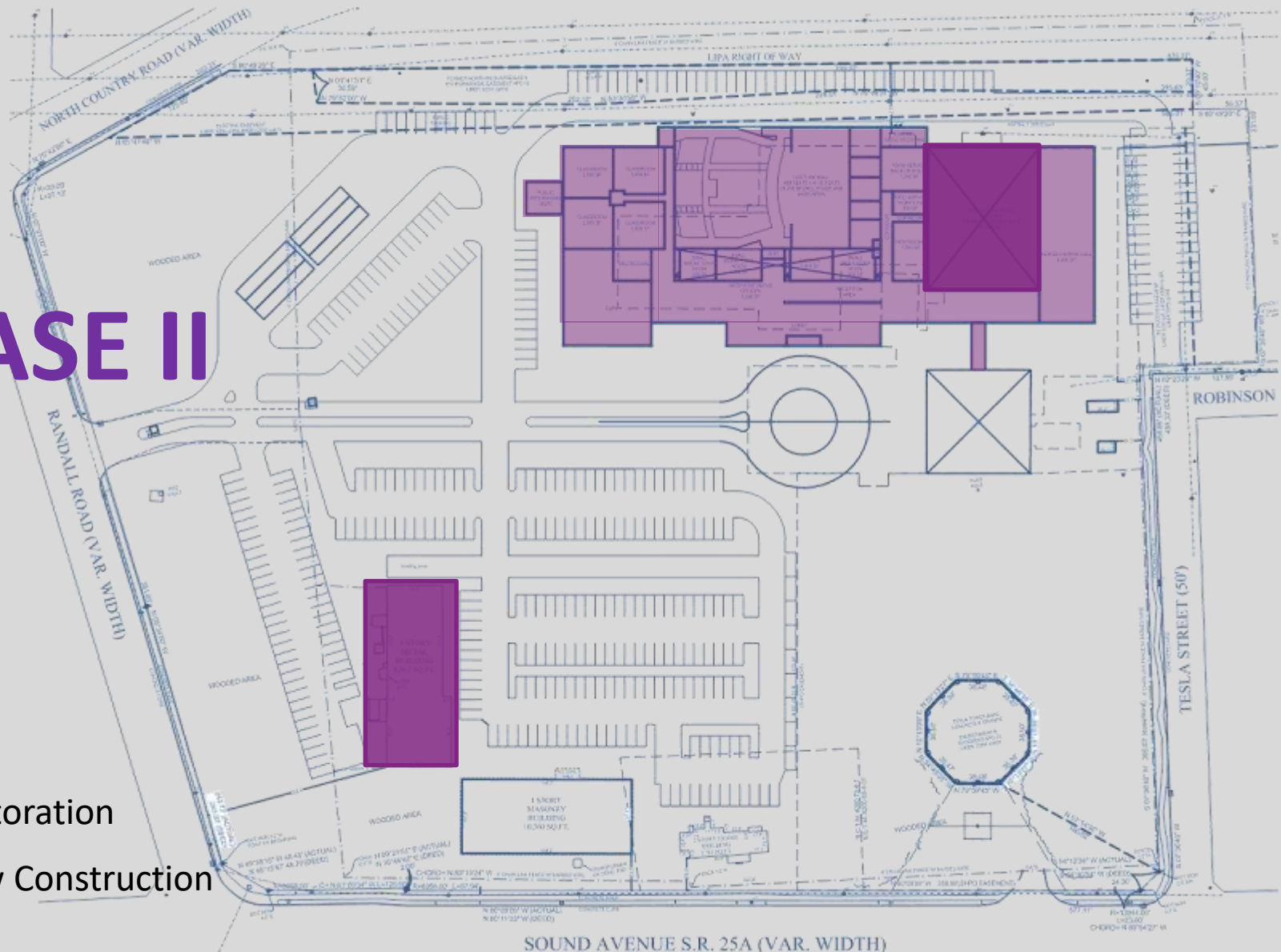
- Restoration
- Demolition



The Future Tesla Science Center

PHASE II

- Restoration
- New Construction





Long Island Section

commends the

**TESLA SCIENCE CENTER AT
WARDENCLYFFE**

For its determination to stimulate innovation and so honor the prolific inventor, Nikola Tesla, through the creation of a world-class science, technology, and engineering educational facility and museum, and featuring the historic Wardenclyffe laboratory of the famed inventor as its centerpiece.

AWARDS CHAIRMAN
JESSE TAUB

LI SECTION CHAIRMAN
M. NAZRUL ISLAM

Books on Tesla

- | | | |
|------|---------|--|
| 2015 | Cooper | <i>The Truth About Tesla: The Myth of the Lone Genius in the History of Innovation</i> |
| 2013 | Carlson | <i>Tesla: Inventor of the Electrical Age</i> |
| 1996 | Seifer | <i>Wizard: The Life and Times of Nikola Tesla</i> |
| 1981 | Cheney | <i>Tesla: Man Out of Time</i> |
| 1944 | O'Neill | <i>Prodigal Genius: The Life of Nikola Tesla</i> |

A Film on Tesla and TSC

- | | | |
|------|----------|----------------------------|
| 2014 | Sikorski | <i>Tower to the People</i> |
|------|----------|----------------------------|

Tesla Science Center at Wardenclyffe

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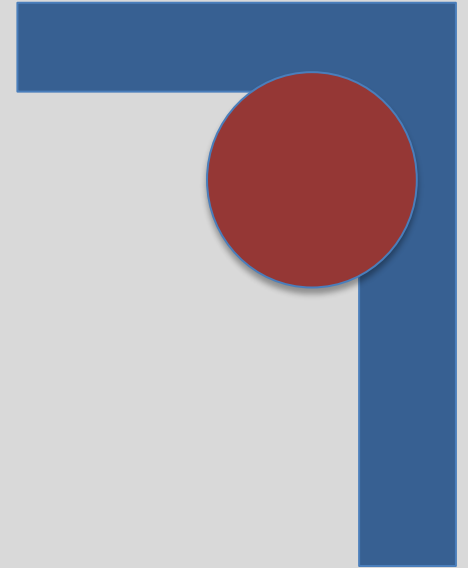
Tesla Science Center

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Email: info@teslasciencecenter.org

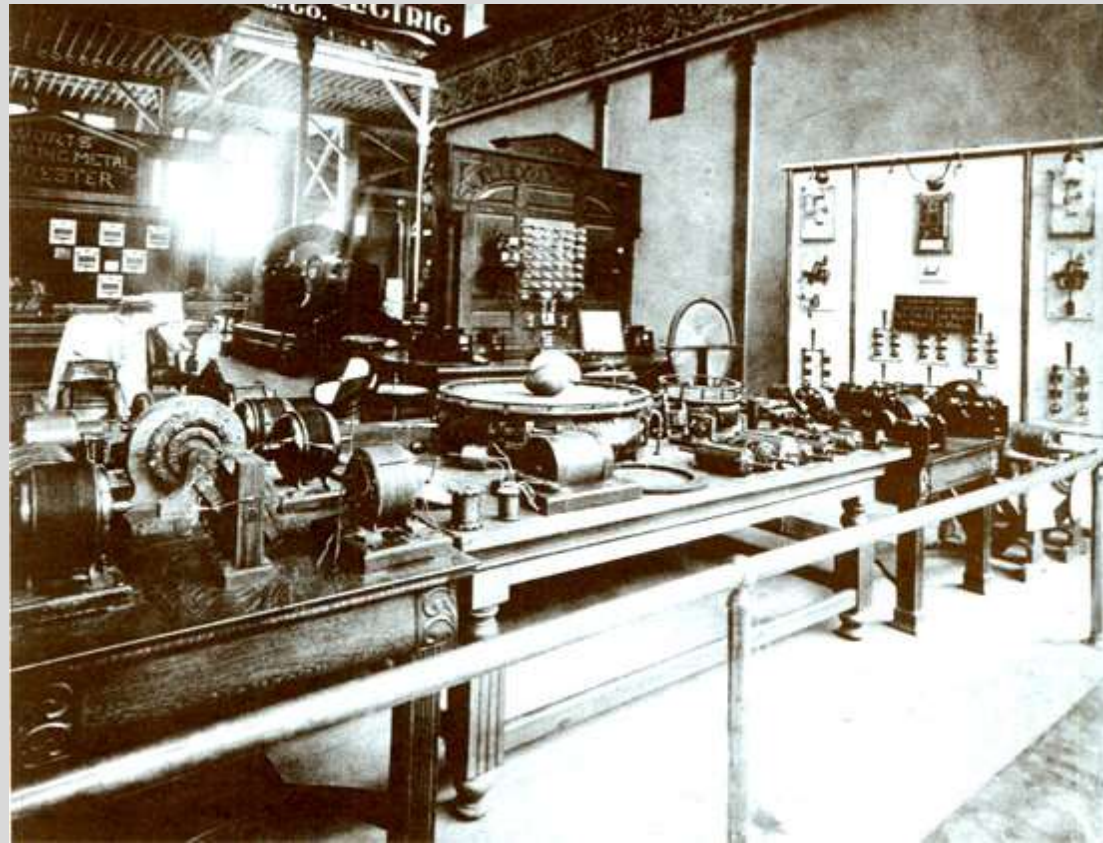
Website: www.tesla.li

Facebook: TeslaScienceCenter



Columbian Exposition

Tesla Exhibit



TSC Mission

From Nikola Tesla's last laboratory, create

Tesla Science Center at Wardenclyffe

1. Nikola Tesla Museum
2. Learning Center
3. Innovation Center
(Maker Space, Incubator)

Short Term Goals

- Site plan – underway
- Fundraising – underway
- Welcome Center – early 2018
- Program Building – 2019
- Remove some buildings near lab - 2018
- Restore lab (please be patient)
- Plan museum, start collection (underway)
- Develop learning center (underway)
- Develop innovation center

Project Phases - Summary

| | Phase 1 | Phase 2 |
|----------|---|---|
| Timeline | 3 years (2017-2019) | 5 years (by 2022) |
| Goals | <ul style="list-style-type: none">- Site plan- Visitor center- Renovation of historic laboratory building- Tesla exhibition space opens- Campus restoration- STEM programming begins | <ul style="list-style-type: none">- Additional exhibition space- Main lobby and reception area- Café- Lecture hall- Flexible event space- Maker space- Incubator lab- Physics playground- STEM classrooms |
| Budget | Construction: \$15 million Program: \$5 million Total: \$20 million | Construction: \$25 million Program: \$5 million Total: \$30 million |

Bauer House and Admin Building

