



Inaugural Lecture

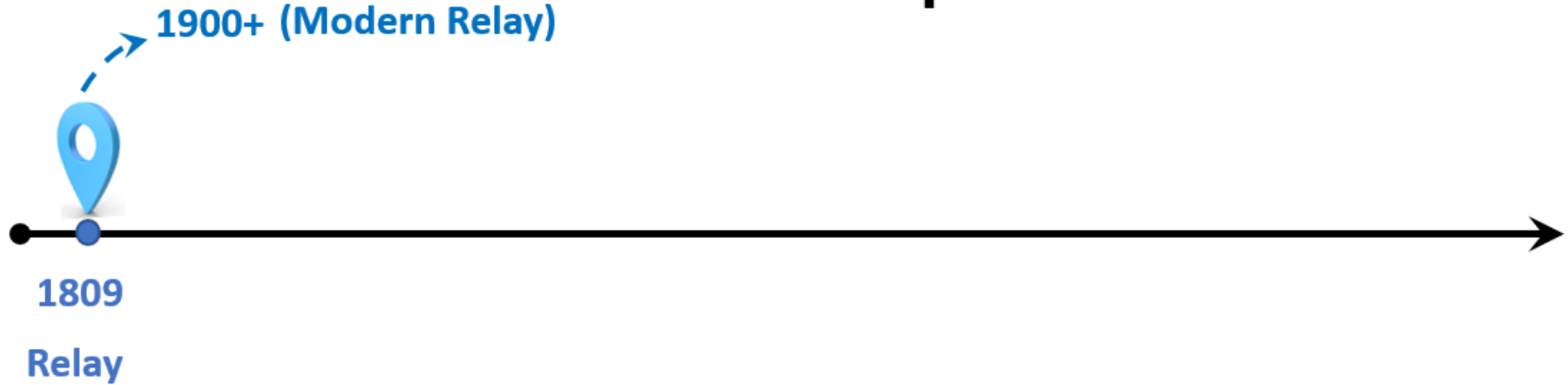
Power Electronics

- View of the Past and Illumination of the Future

Prof. Rupert Gouws



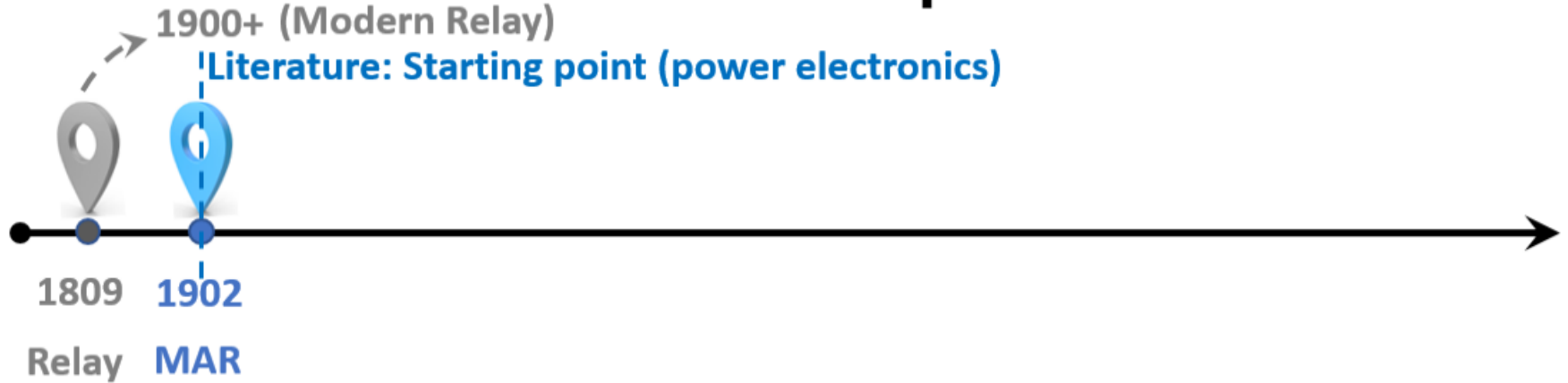
Timeline towards modern power electronics



Relay

- Relay - Is an electrically operated switch^[8].
- Designed - Samuel Thomas von Sömmerring (1809)^[9].
- Invented - Joseph Henry (1835)^{[16]-[19]}.
- Traditional relay applications - Telephone exchanges and early computers to perform logical operations^[8].
- Modern relay applications - Protecting power systems, lines and generators, and high capacity power relays for solar applications^{[13]-[15]}.

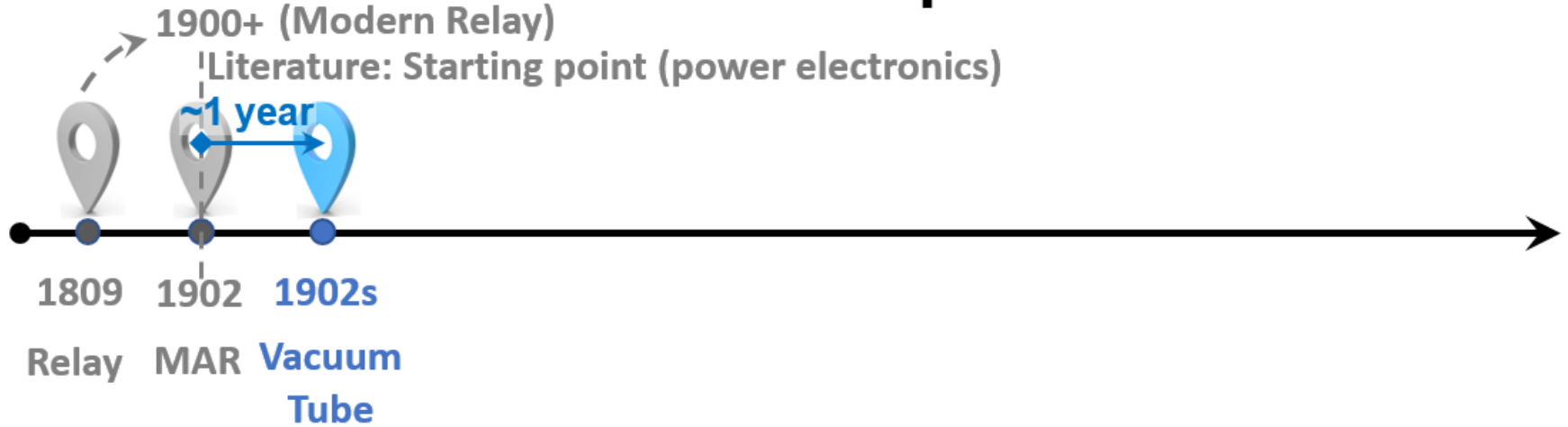
Timeline towards modern power electronics



Mercury Arc Rectifier (MAR)

- Mercury Arc Rectifier (MAR) - Type of electrical rectifier that converts high-voltage/current AC into DC^[27].
- Invented - Peter Cooper Hewitt (1902)^[30].
- MAR - Consist of a cathode gas-filled tube, which is made from a pool of liquid mercury, making it self-restoring^{[28],[29]}.
- MAR applications - Industrial motors, electric railways, streetcars, electric locomotives, radio transmitters, HVDC power transmission^[30].

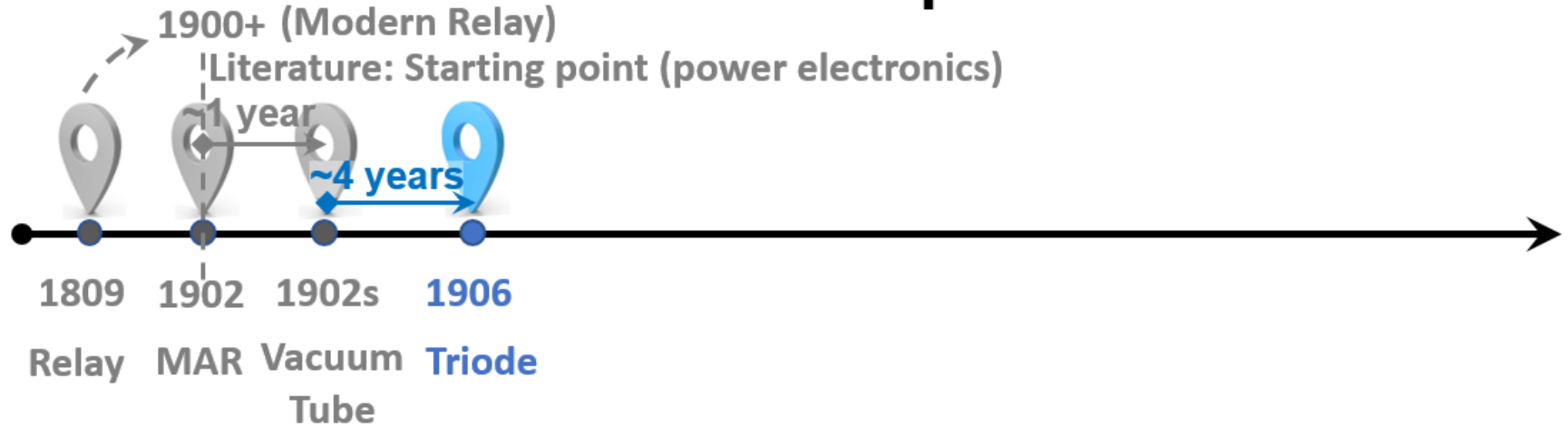
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Vacuum Tube

- Vacuum tube - Device that controls electric current flow in a high vacuum between electrodes when electric potential difference has been applied^{[35]-[37],[39]}.
- Invented - John Ambrose Fleming (1904)^[34].
- Vacuum tubes applications - Radio, television, radar, sound recording, long-distance telephone networks, early digital computers^[24].

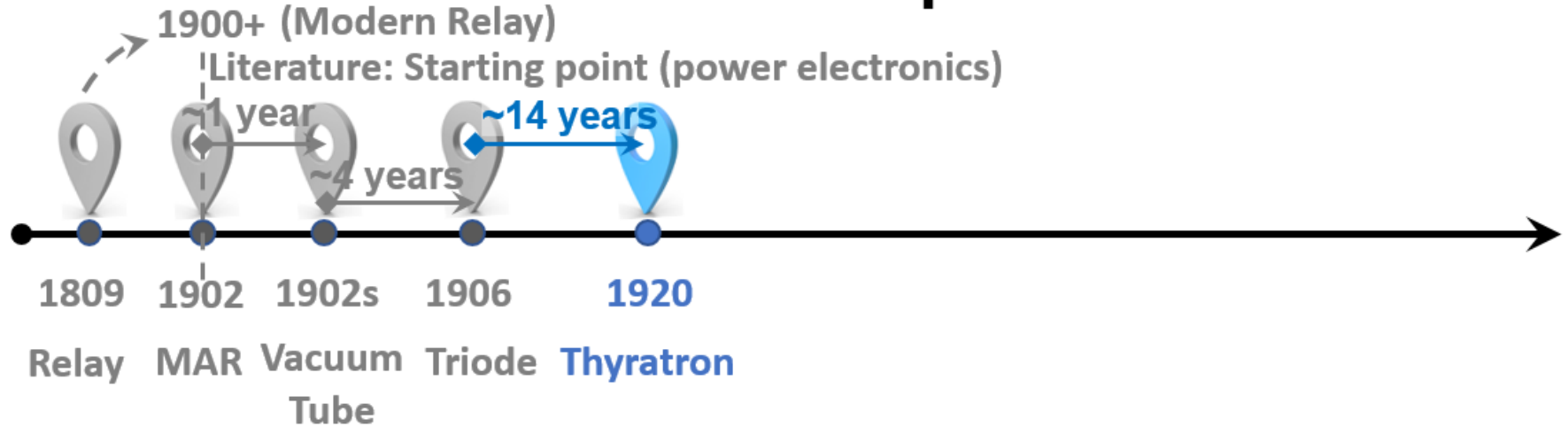
Timeline towards modern power electronics



Triode

- Triode - First practical electronic amplifier^[42].
- Invented/developed - Lee de Forest (1906)^[42].
- Triode Audion - First triode, consisting of an evacuated glass tube containing three electrodes^{[44],[46]-[49]}.
- Triode applications - Long-distance telephone, radios, televisions, high-power RF amplifiers, radio transmitters, industrial RF devices^{[42],[50]}.

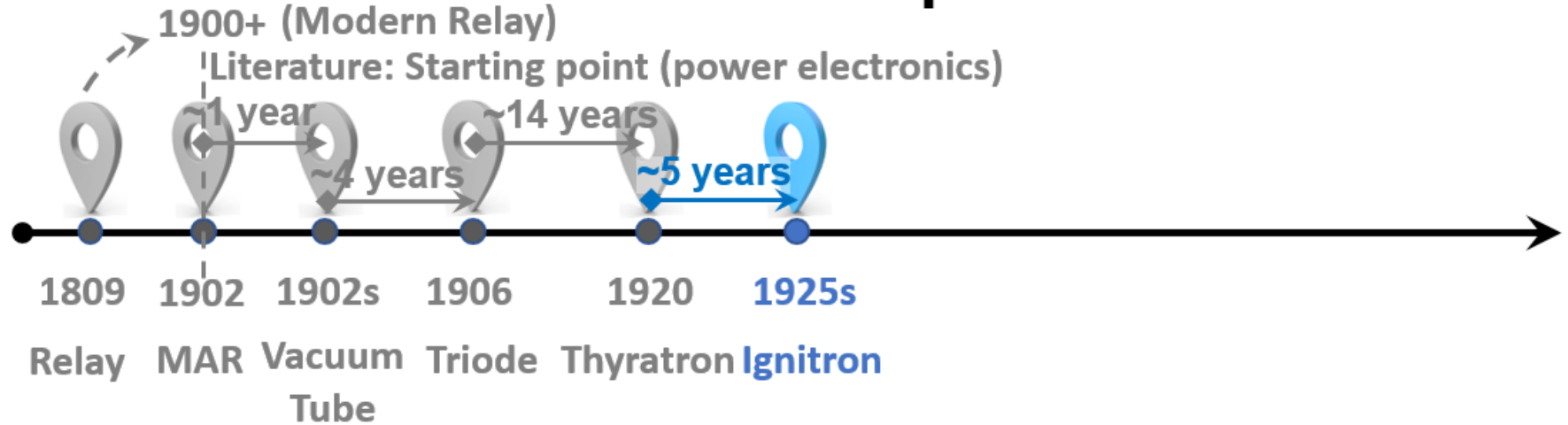
Timeline towards modern power electronics



Thyratron

- Thyratron - Type of gas-filled tube used as a high-power electrical switch and controlled rectifier^{[52],[53]}.
- First investigators - Irving Langmuir and G.S. Meikle (1914/1920)^[54].

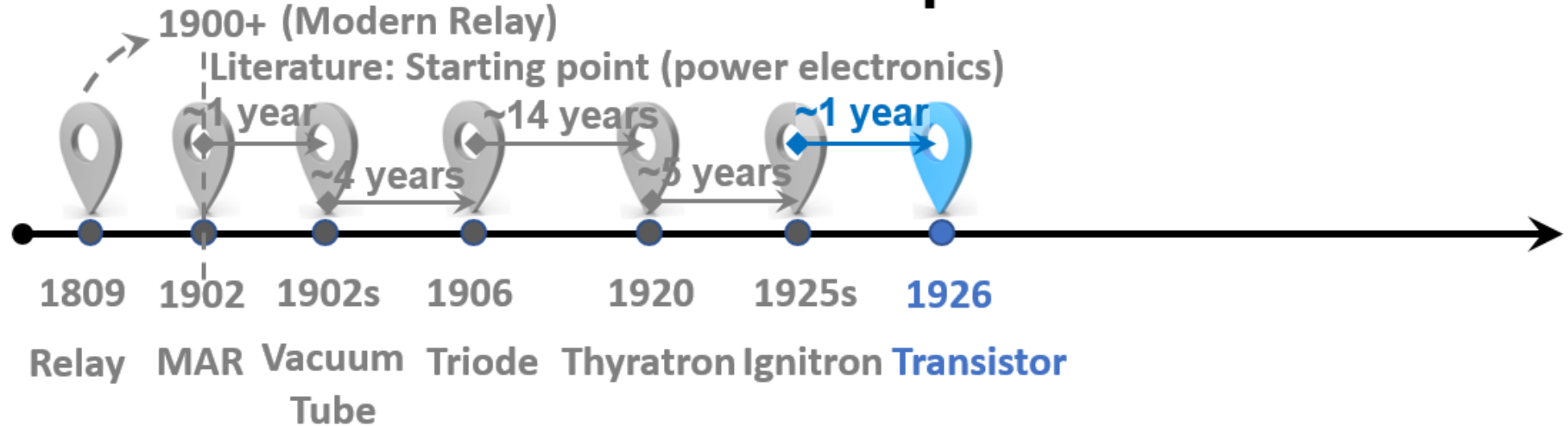
Timeline towards modern power electronics



Ignitron

- Ignitron - Type of gas-filled tube used as a controlled rectifier^[62].
- Invented - Joseph Slepian (1925/1930)^[60].
- Ignitrons - Related to MARs, but the arc is differently ignited^[60].

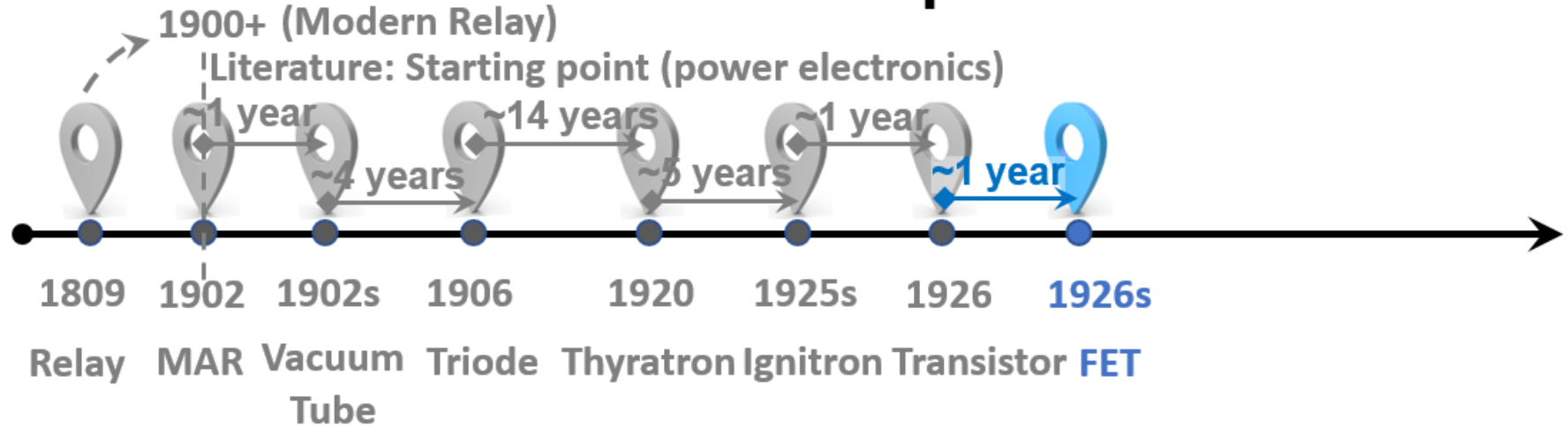
Timeline towards modern power electronics



Transistor

- Transistor - Semiconductor device used to amplify/switch electronic signals and electrical power^[66].
- Transistors - Generally smaller and require less power compared to vacuum tubes ^[67].
- Transistors - Paved the way for smaller and cheaper computers, radios and calculators^{[68],[72]}.

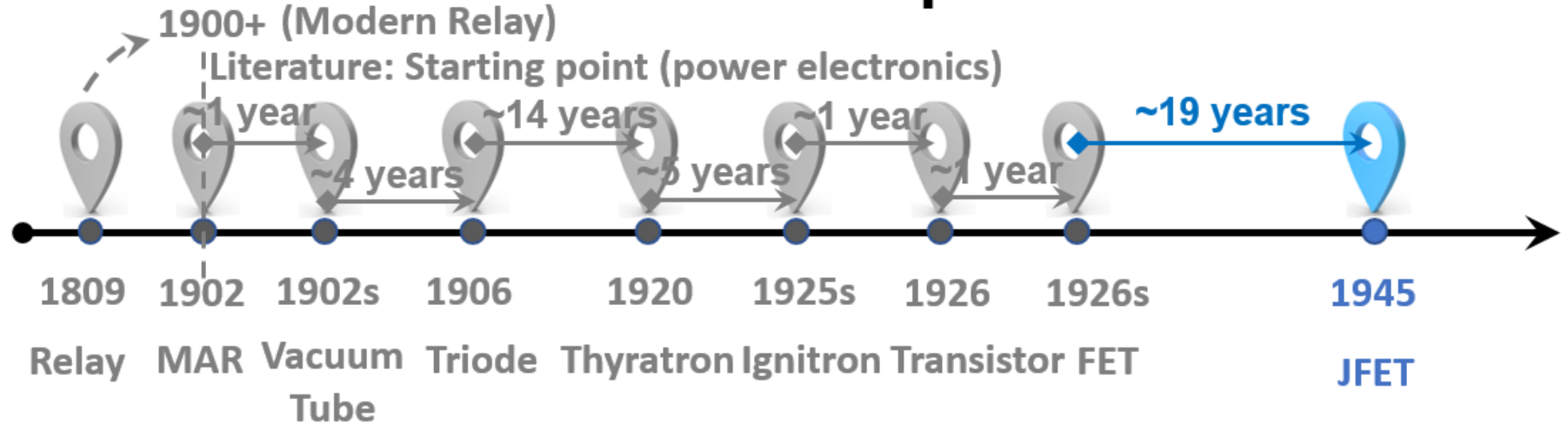
Timeline towards modern power electronics



FET

- Field-effect transistor (FET) - Type of transistor that uses electric field to control the flow of current^[78].
- First patented - Julius Edgar Lilienfeld(1925) and Oskar Heil(1934)^[77].
- FET - Used in noise-sensitive electronics: tuners, low-noise amplifiers for VHF and satellite receivers^{[79],[80]}.

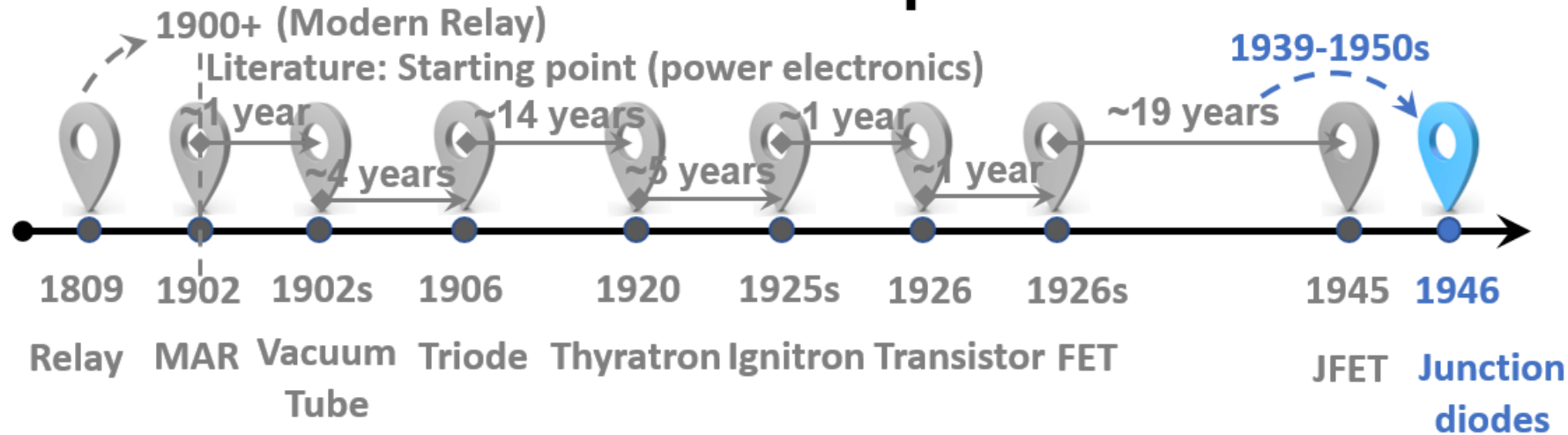
Timeline towards modern power electronics



JFET

- Junction-gate field-effect transistor (JFET) - One of the simplest types of FET^[82].
- First patented - Heinrich Welker (1945)^[83].
- JFET - Exclusively voltage-controlled in that they do not need a biasing current^[82].

Timeline towards modern power electronics



Junction Diodes (p–n and Schottky Diode)

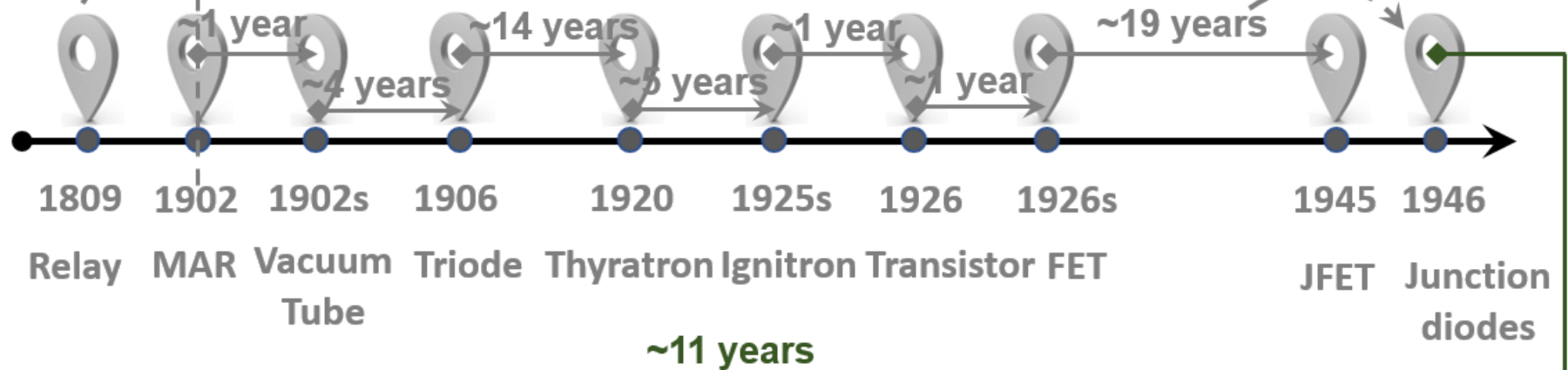
- Diode - Two-terminal electronic component that conducts current primarily in one direction^[91].
- Invented - P-N junction diodes - Russell Ohl (1939)^[95].
- Development - P-N junction diodes started early 1950s^[87].
- Invented - Schottky effect (later Schottky barrier diodes) - Walter Schottky (1914)^{[86],[97]}.
- Manufacturing of 1N34 crystal diodes - Sylvania Electric Products Inc. (1946)^{[88]-[90]}.

Timeline towards modern power electronics

1900+ (Modern Relay)

Literature: Starting point (power electronics)

1939-1950s



~11 years

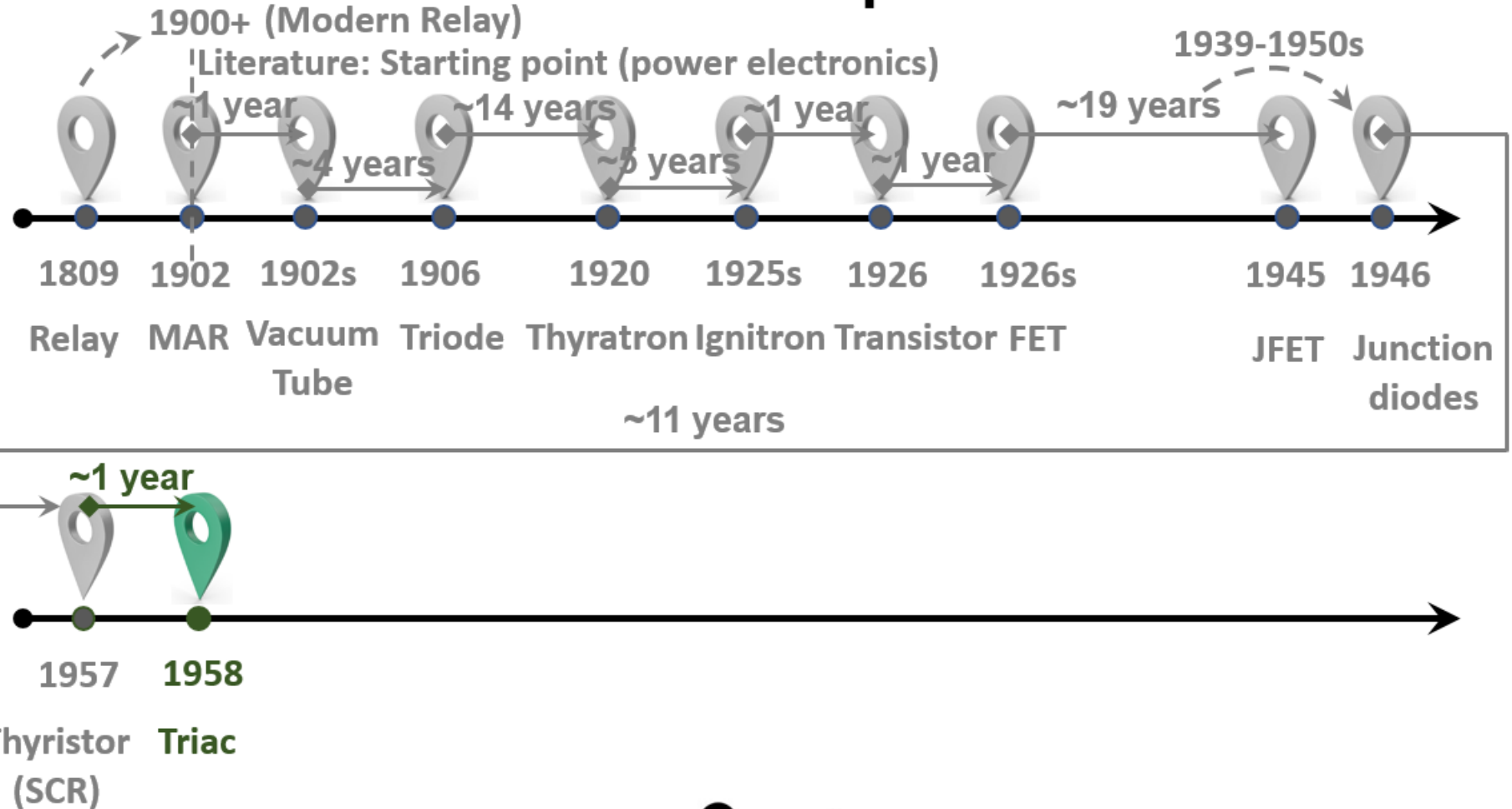
1957

Thyristor
(SCR)

Thyristor

- Thyristor or silicon-controlled rectifier (SCR) - Solid-state semiconductor device with four layers of alternating P- and N-type materials that acts as a bistable switch^[102].
- Proposed - William Shockley (1950)^[103].
- Commercialized - Frank W. "Bill" Gutzwiller (1957)^[114].
- Thyristors applications - Control light dimmers and high-voltage DC power transmission, and electric motor speed control^[103].

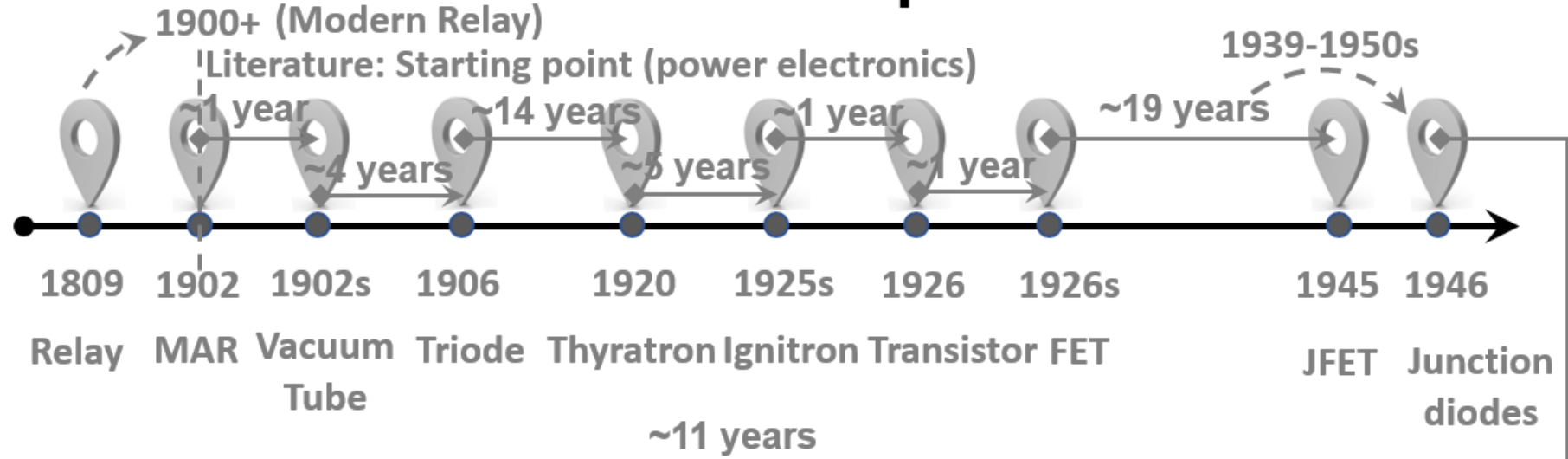
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Triac

- Triac - AC Triode - Three terminal electronic component that conducts current in either direction when triggered^{[108],[109]}.
- Inventor - Frank W. "Bill" Gutzwiller (1958)^[115].
- The bidirectionality of TRIACs makes them convenient switches for AC applications^{[110],[111]}.

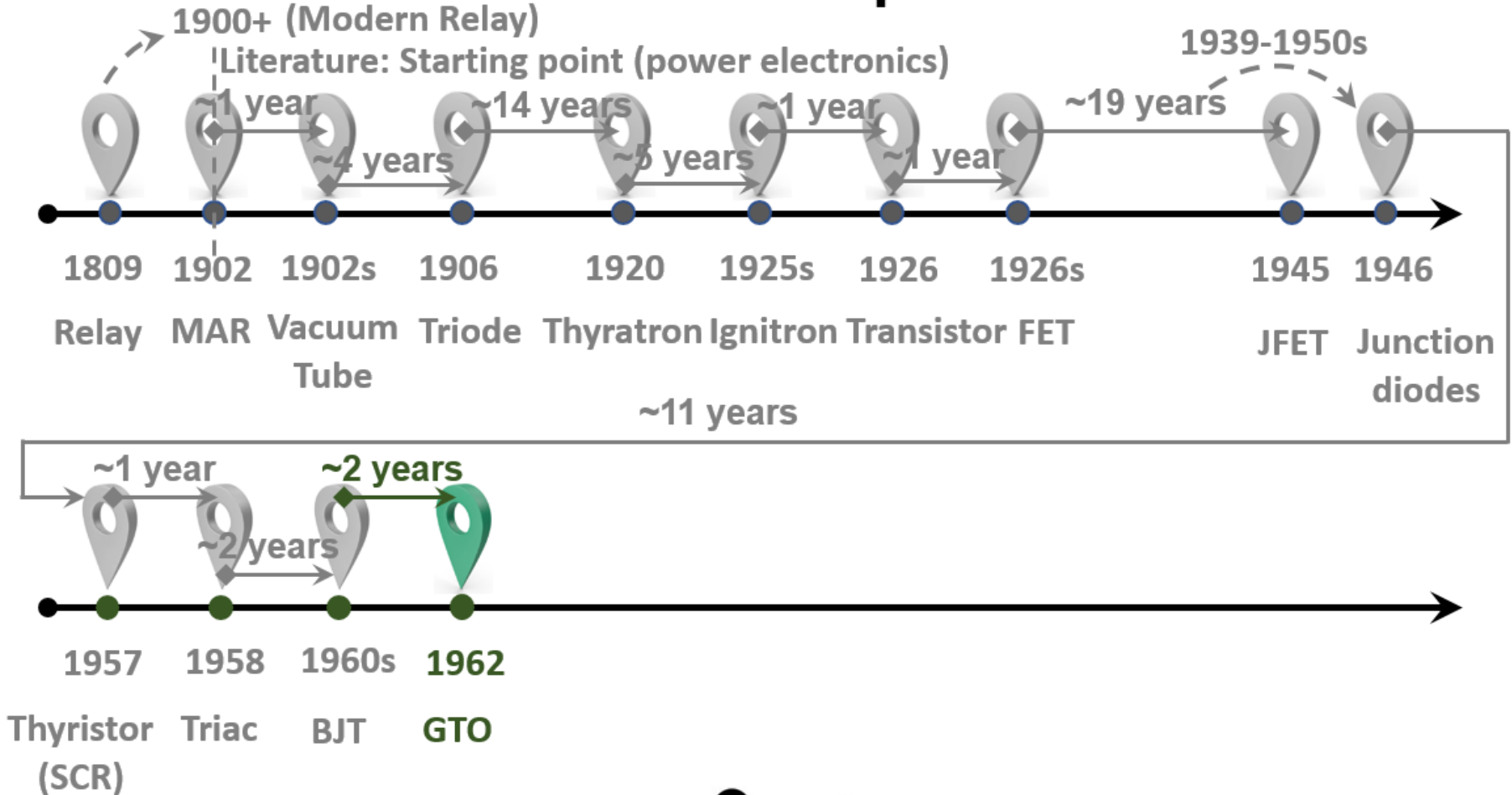
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BJT

- Bipolar junction transistor (BJT) - Type of transistor that uses both electrons and electron holes as charge carriers^[117].
- Invented - William Shockley (Invented: 1948, Production: 1960s)^[124].
- BJT applications - Radio-frequency amplifiers, high voltage switching, switching heavy currents, and used in digital circuits^[117].

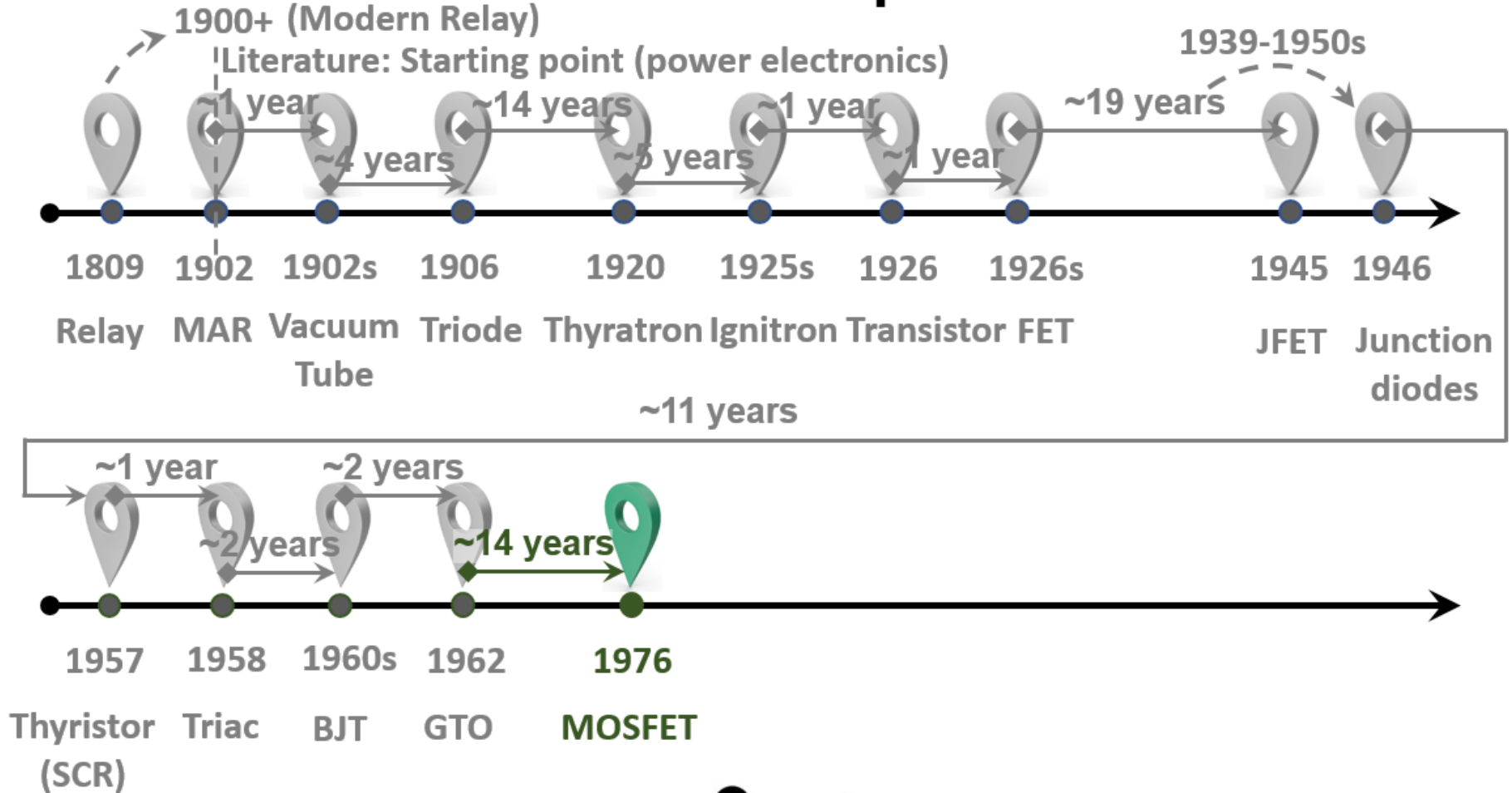
Timeline towards modern power electronics



GTO

- Gate turn-off thyristor (GTO) - Special type of high-power thyristor which is fully controllable^[119].
- Invented - General Electric Company (1962)^[119].
- GTO turn off time - Ten times faster than that of comparable SCR^[120].
- GTO applications - Variable speed motor drives, high power inverters and traction^[121].

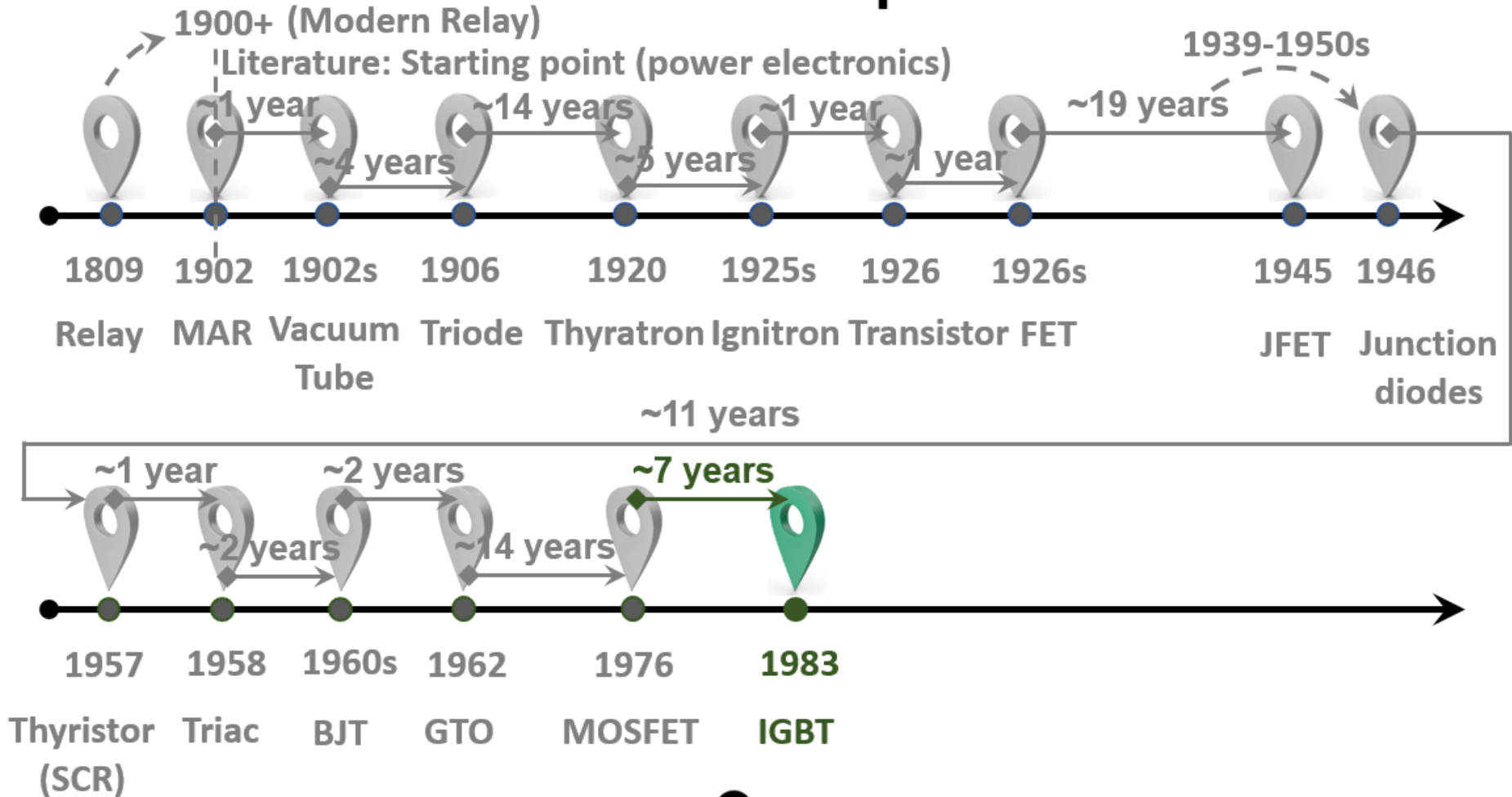
Timeline towards modern power electronics



MOSFET

- Metal–oxide–semiconductor field-effect transistor (MOSFET) - Type of insulated-gate FET that is fabricated by the controlled oxidation of a semiconductor^[131].
- Invented - Mohamed Atalla and Dawon Kahng (1959/1960)^[131].
- Production - Power MOSFET - 1976^[140].
- Power MOSFET - Most widely used low-voltage (<200 V) switch in the world^{[129],[130]}.

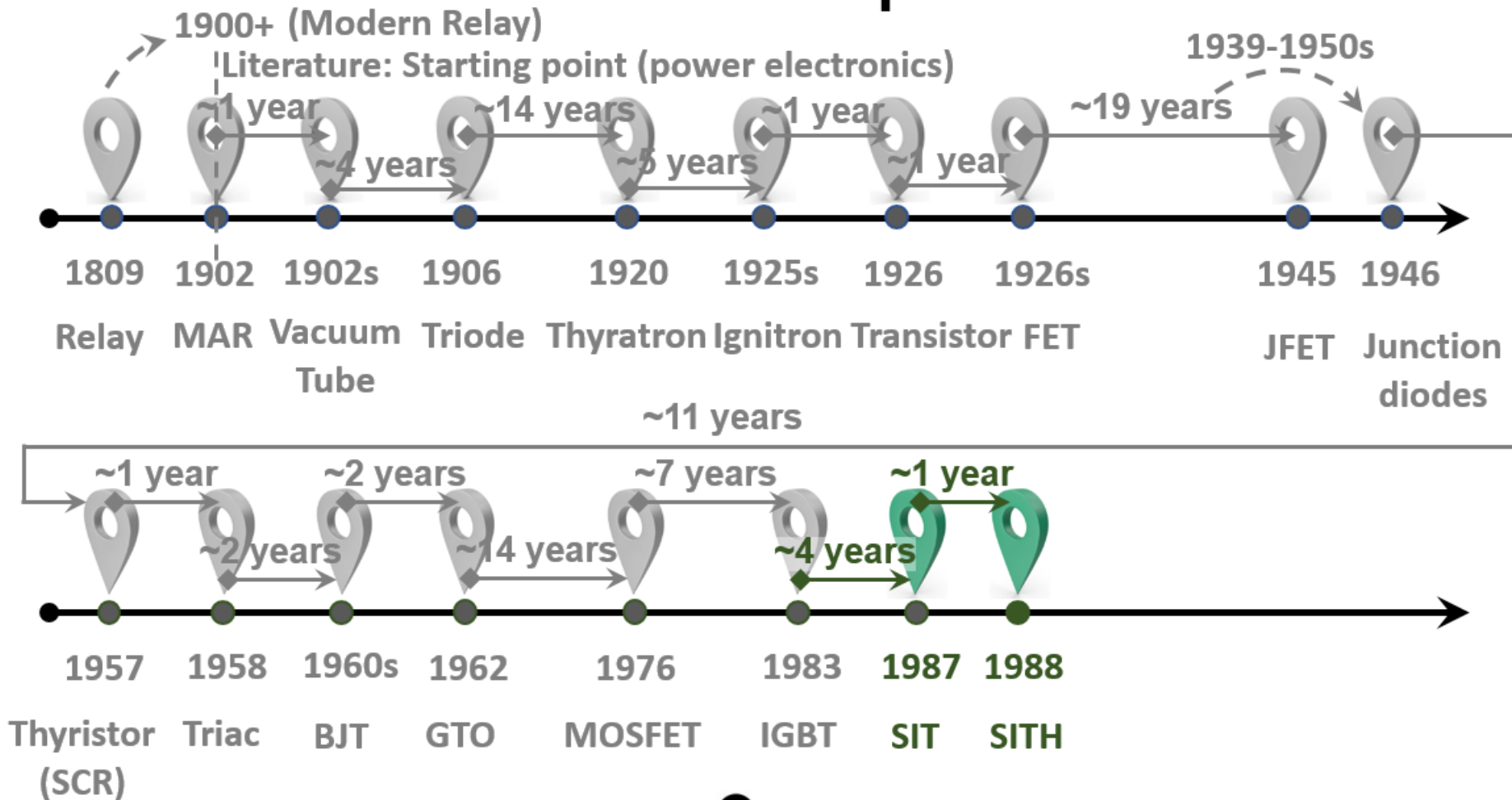
Timeline towards modern power electronics



IGBT

- Insulated-gate bipolar transistor (IGBT) - Three-terminal semiconductor power switch that reduced gasoline consumption by 10% and improved electrical energy efficiency by more than 40%^[138].
- Invented - Bantval Jayant Baliga (1983)^[139].
- IGBT applications - Switching power supplies, variable-frequency drives, electric cars, trains, arc-welding machines, air conditioners^{[132],[138]}.
- IGBT - 2010 - Second most widely used power transistor, after the power MOSFET^[135].

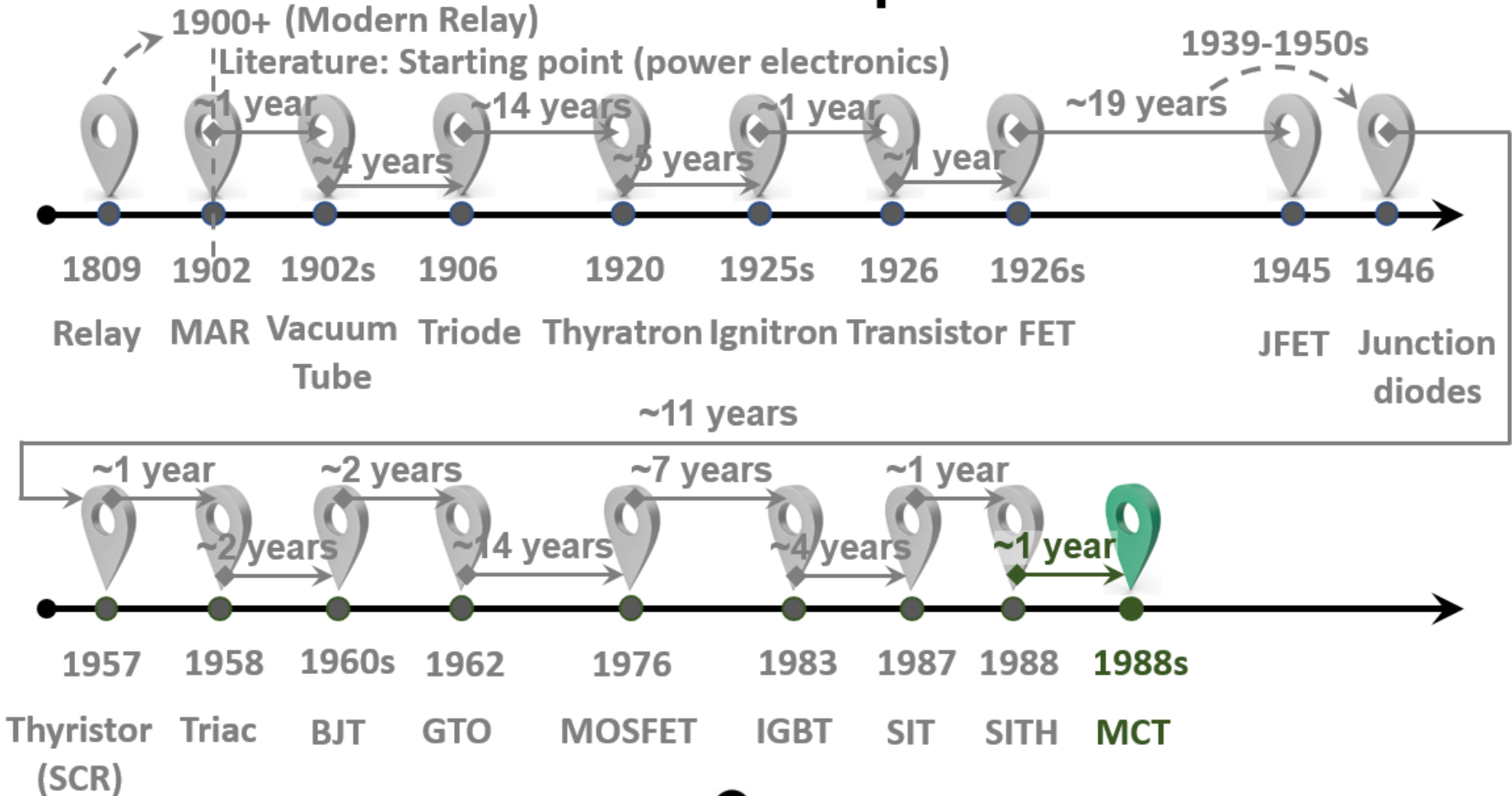
Timeline towards modern power electronics



SIT and SITH

- Static induction transistor (SIT) - High power/frequency transistor device^[141].
- SIT - Higher breakdown voltages than a FET^[141].
- Invented - SIT - Jun-ichi Nishizawa and Y. Watanabe (Inv: 1950, Prod: 1987)^[157].
- Static induction thyristor (SITh) - Thyristor with buried gate structure - Gate electrodes are placed in the n-base region^[145].
- SITh - Low noise/distortion, high audio frequency power capability^{[146]-[148],[152]}.
- Invented - SITh - Jun-ichi Nishizawa (Invented: 1975, Production: 1988)^[159].

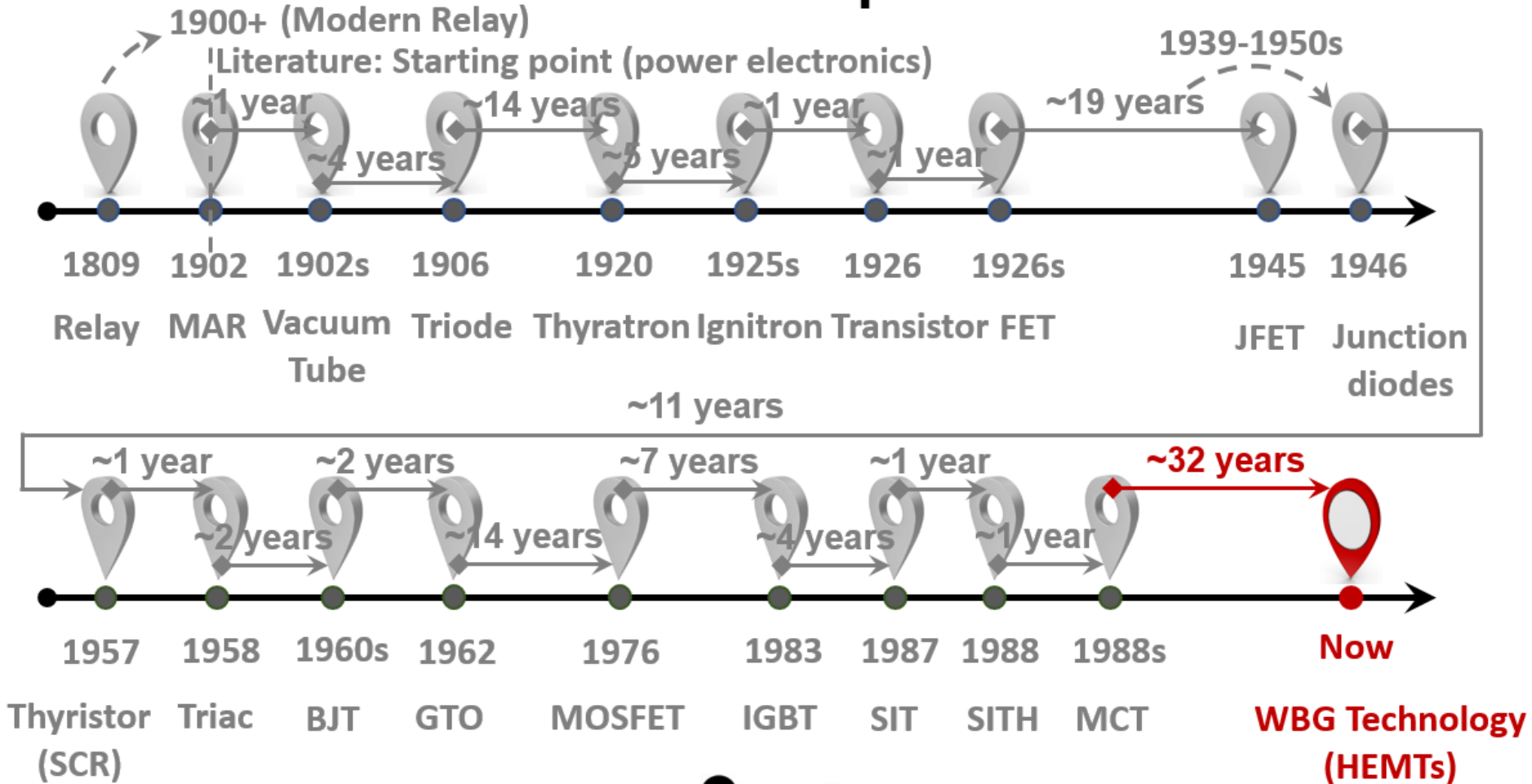
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MCT

- MOS-controlled thyristor (MCT) - Fully voltage-controlled thyristor, which is controlled by MOSFETs^[151].
- Invented - V.A.K. Temple (Invented: 1984, Production: 1988s)^[150].
- MCT - Low forward conduction drop, low switching losses, high gate input impedance and fast switching time^[153].

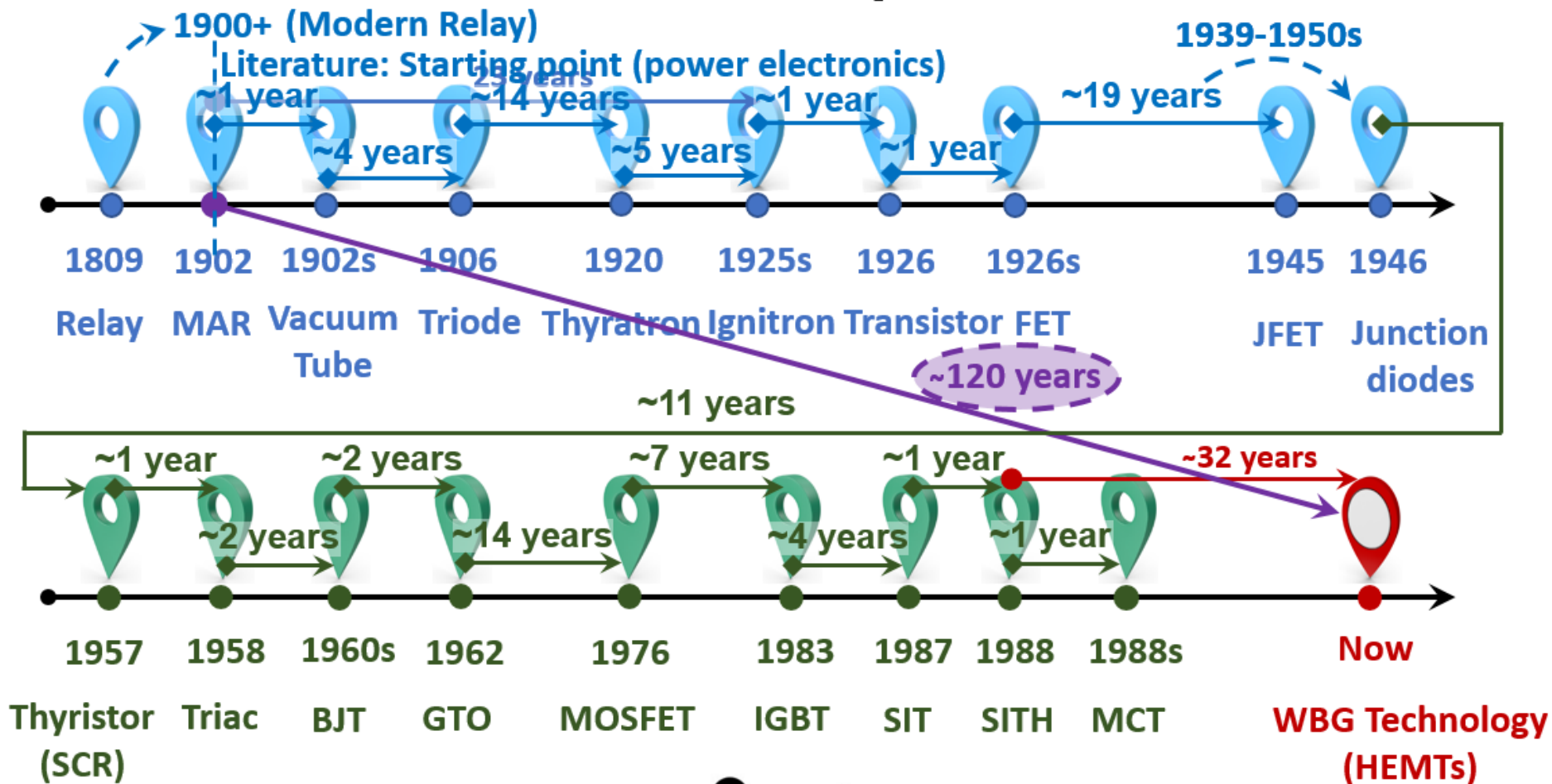
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High-Electron-Mobility Transistor (HEMT)

- High-electron-mobility transistor (HEMT) - FET incorporating a junction between two materials with different band gaps^[165].
- HEMT - High-frequency performance, high-power performance, high switching speeds, low noise^{[165]-[168]}.
- Invented – HEMT - Takashi Mimura (Invented: 1979, developed: 1985)^[166].
- Developed - GaN-based HEMT – Khan (1993)^[175].
- Developed - MOS-HEMT - P.D. Ye and B. Yang (2004)^[176].
- New developments/applications - GaN-on-Si HEMT and AlGaN/GaN HEMT – Various authors (2020/2021)^{[172]-[174]}.

Timeline towards modern power electronics



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