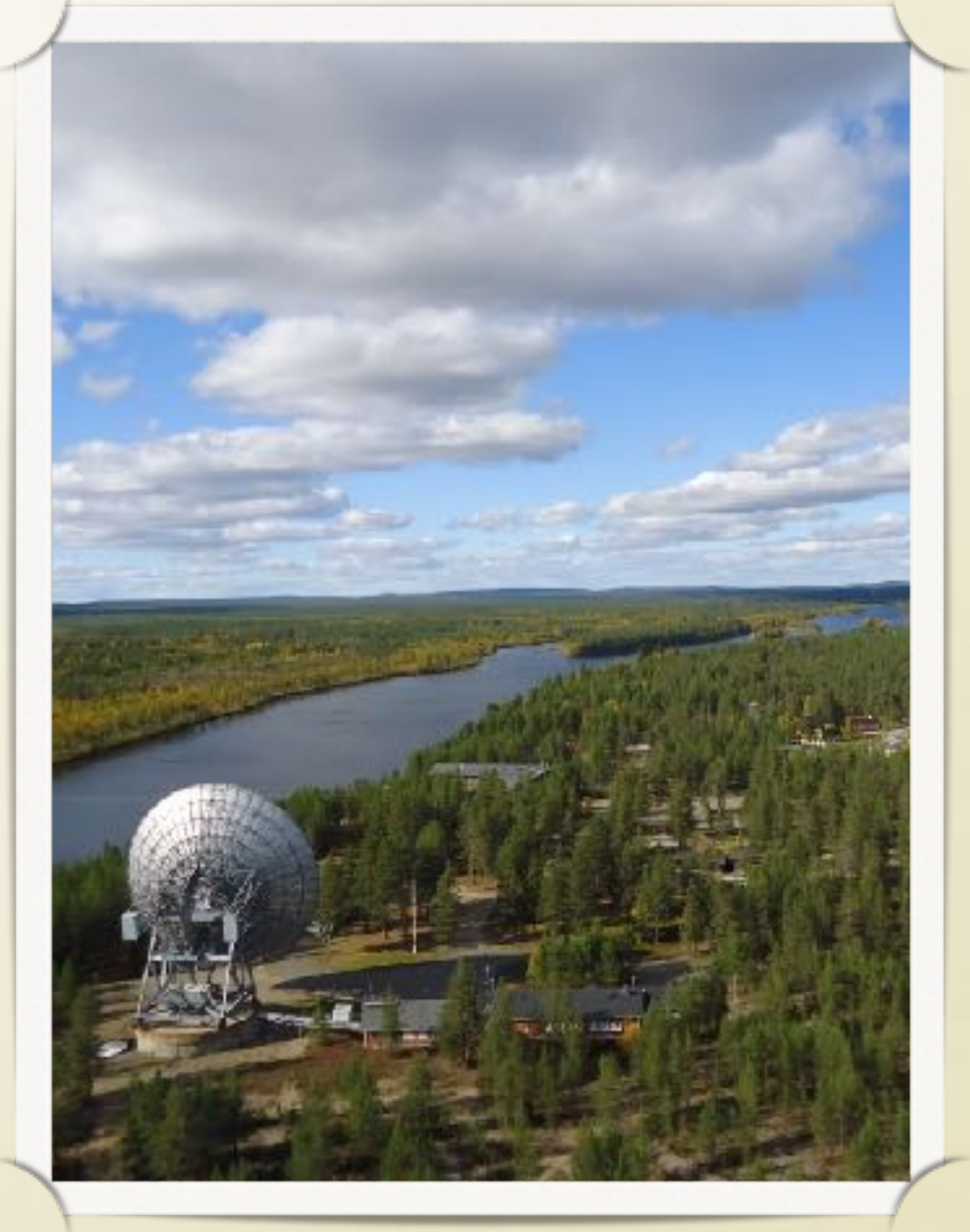
History of RADAR

Thomas Ulich
Sodankylä Geophysical Observatory
Finland

Sodankylä Geophysical Observatory

- Established by Finnish Academy of Science and Letters in 1913.
- Finland independent from Russia 1917.
- Part of University of Oulu since 1st August 1997.
- National Task.



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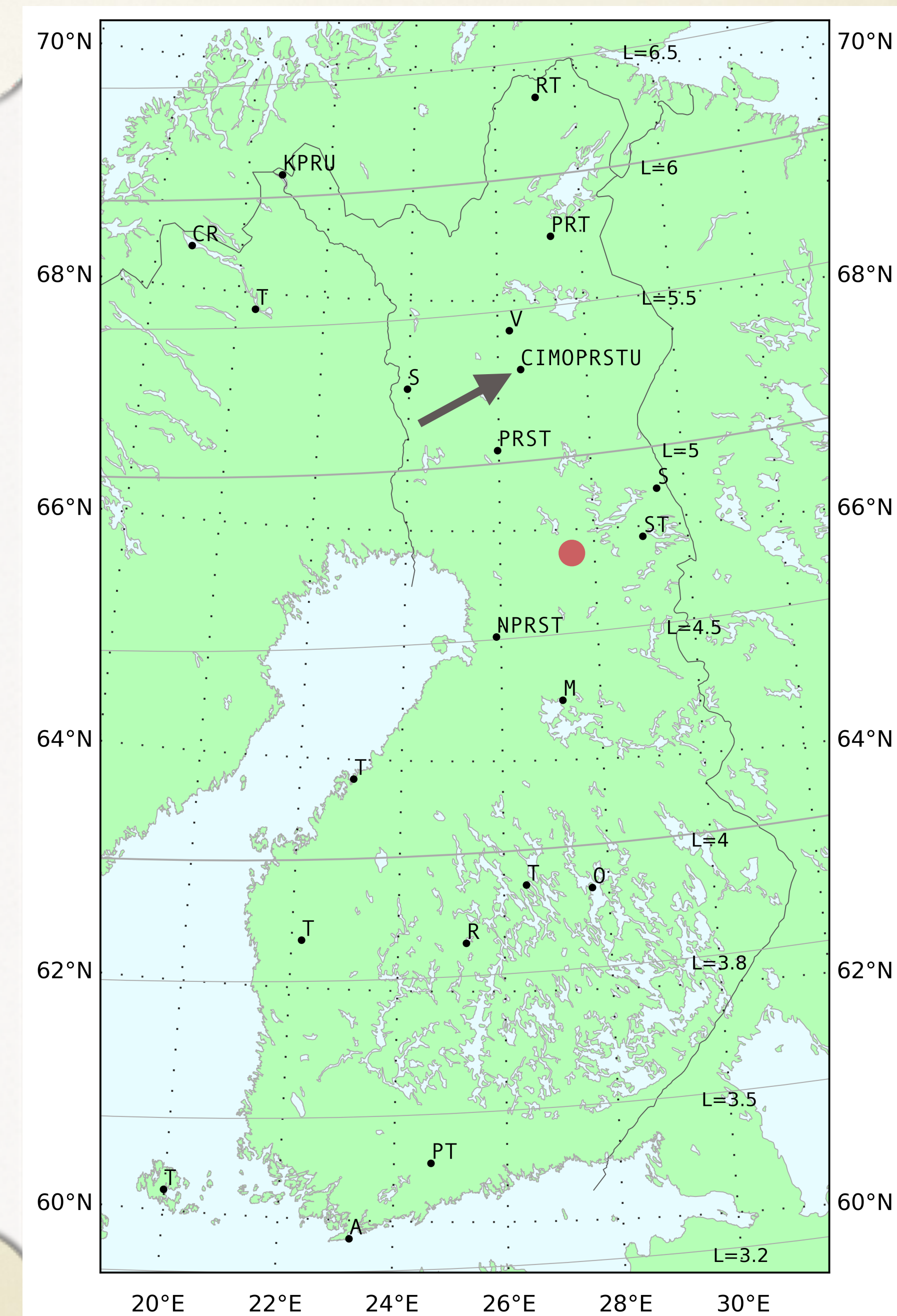


International Polar Year 1882/‘83

Sodankylä

Suomen polaariasema.

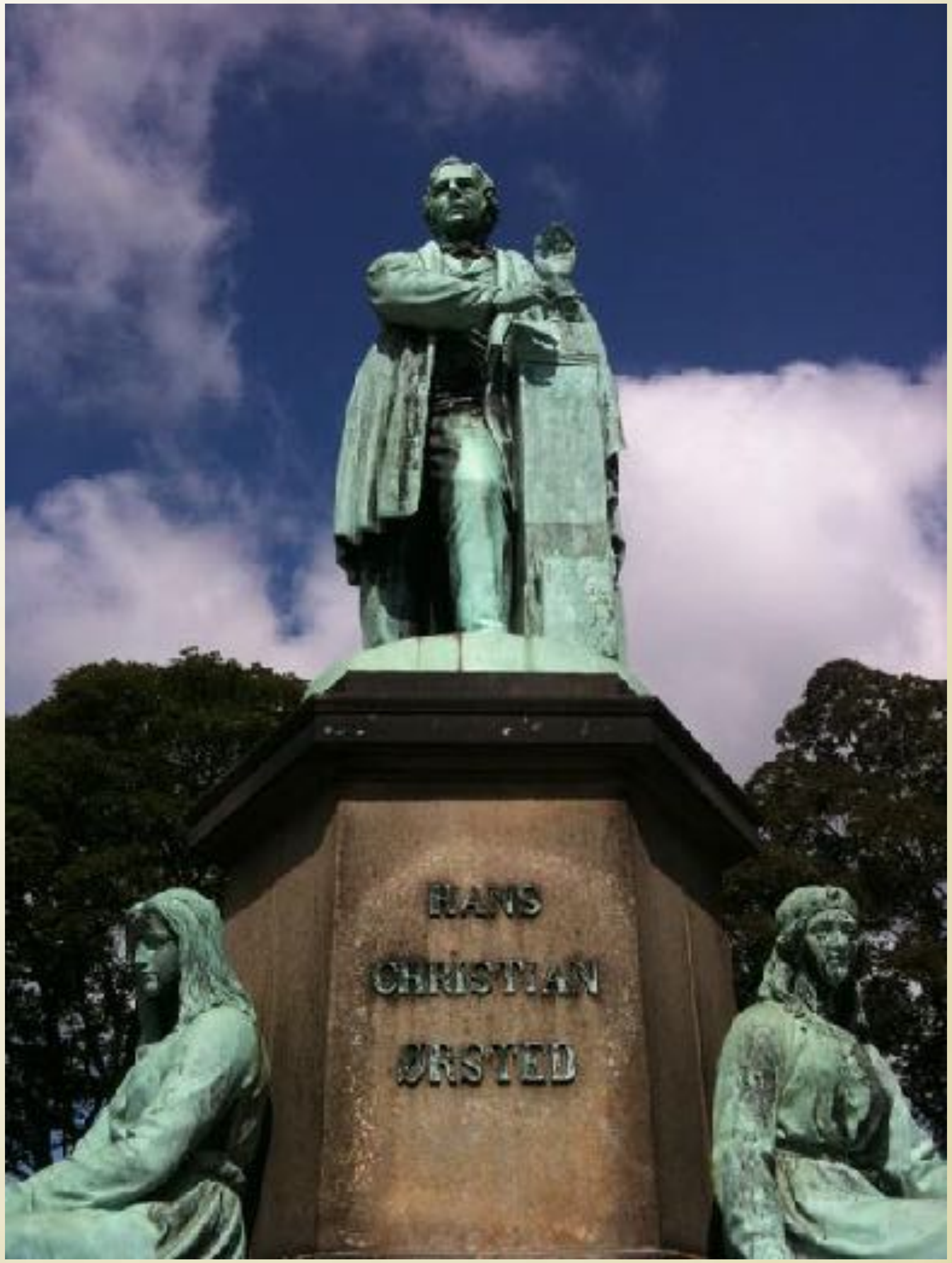
Observatory?

- Monitoring Earth's Environment
  - Continuously, long-term, indefinite
  - High Quality
  - Well documented
  - Reference
- If all else fails, keep measuring
- Produces data for others: "We produce data for scientists, who are not born yet." (Urban Brändström)

Johannes Kultima (1944-2014) at the zenith telescope. Photo: SGO Archive.

Hans Christian Ørsted

On 21st April 1820, Ørsted discovered a direct relationship between electricity and magnetism, which prompted much research into electrodynamics.



(14 August 1777 – 9 March 1851)

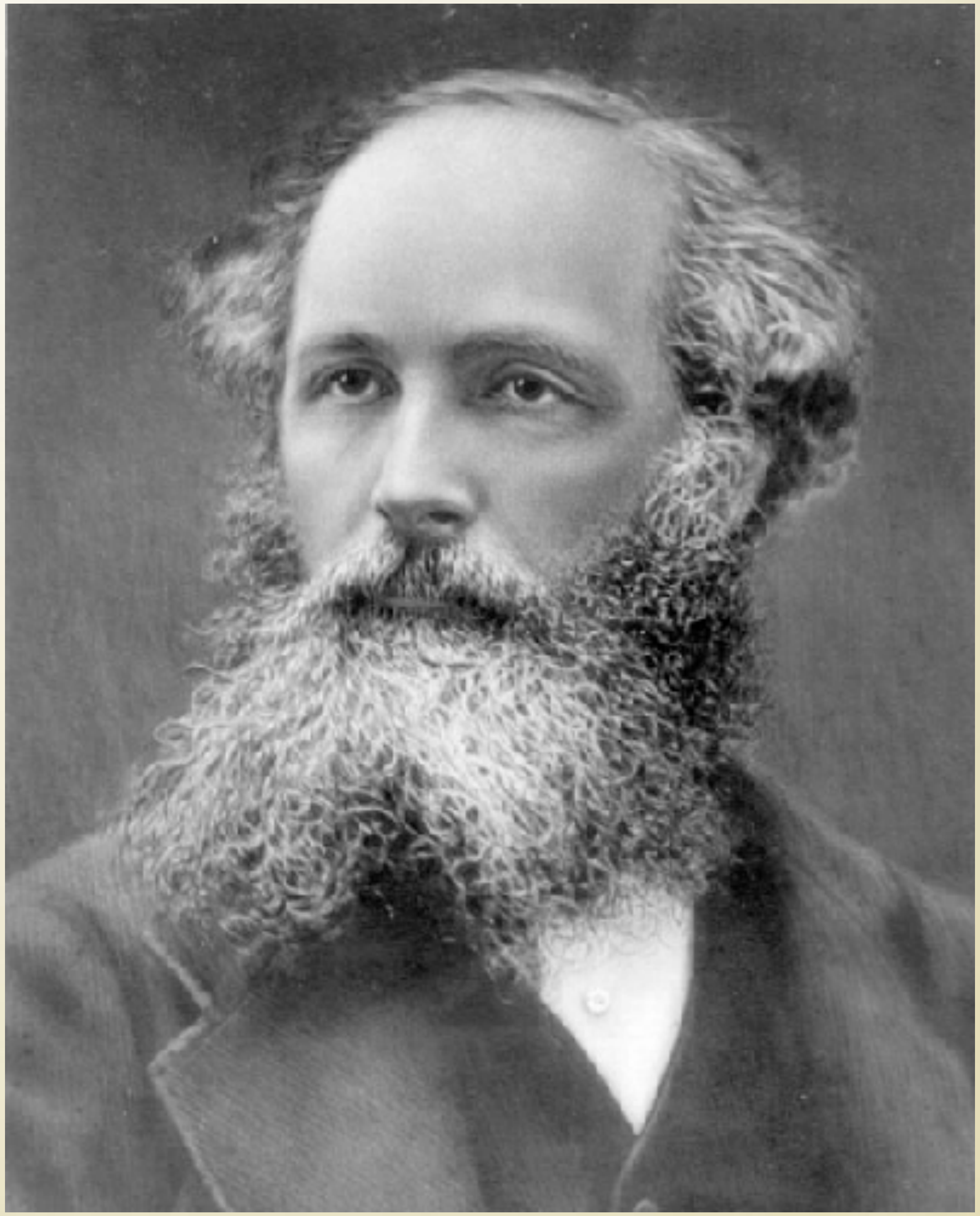
André-Marie Ampère

Inspired by Ørsteds discovery, Ampère developed a mathematical theory describing electromagnetic phenomena and predicting many new ones.

(20th January 1775 – 10th June 1836)

James Clerk Maxwell

The Maxwell Equations showed that electricity and magnetism are two aspects of the same force (1862).



(13 June 1831 – 5 November 1879)

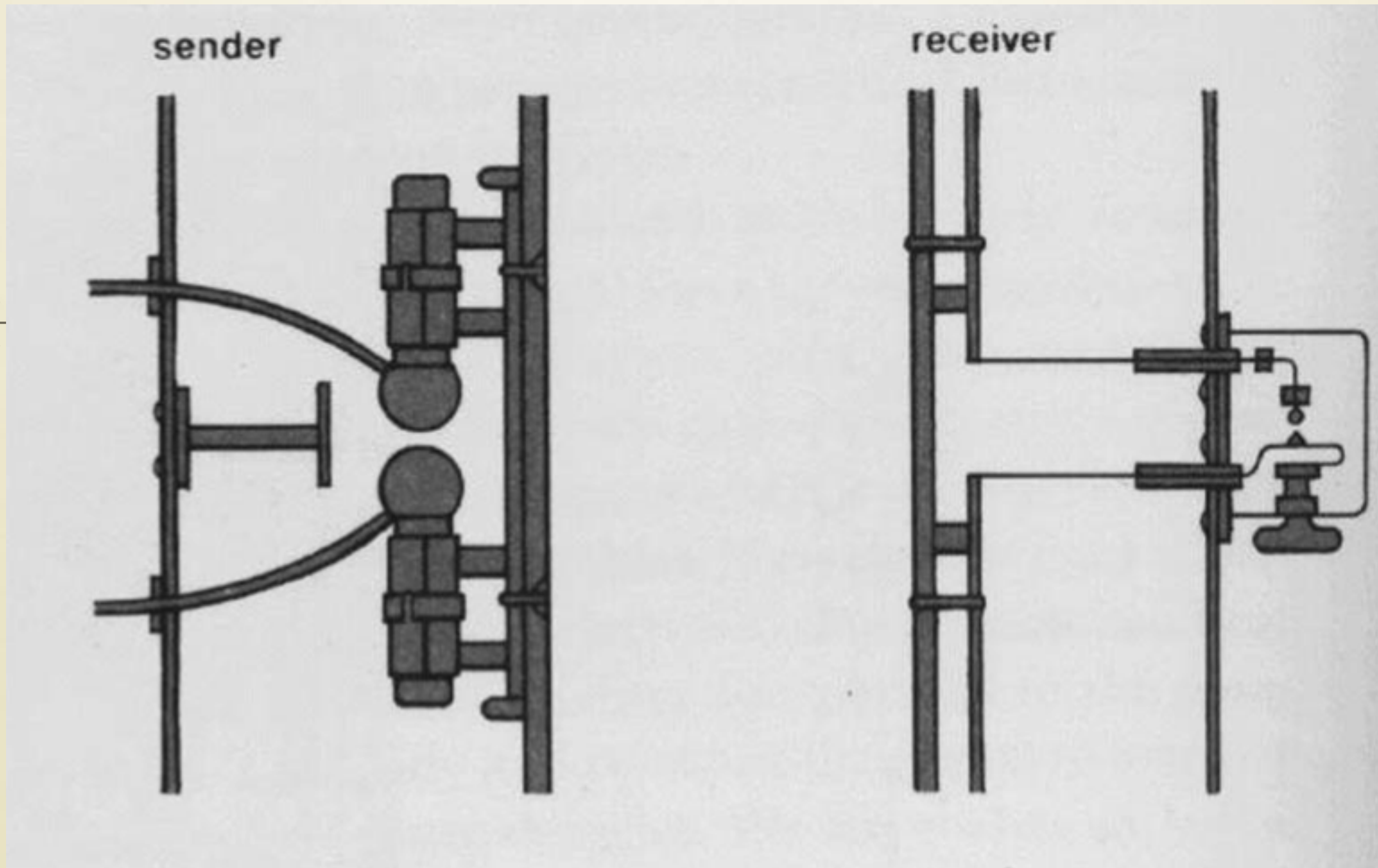
Heinrich Rudolf Hertz

Hertz proved that electricity can be transmitted by electromagnetic waves in 1888.

(22 February 1857 – 1 January 1894)

Heinrich Rudolf Hertz

H



(22 February 1857 – 1 January 1894)

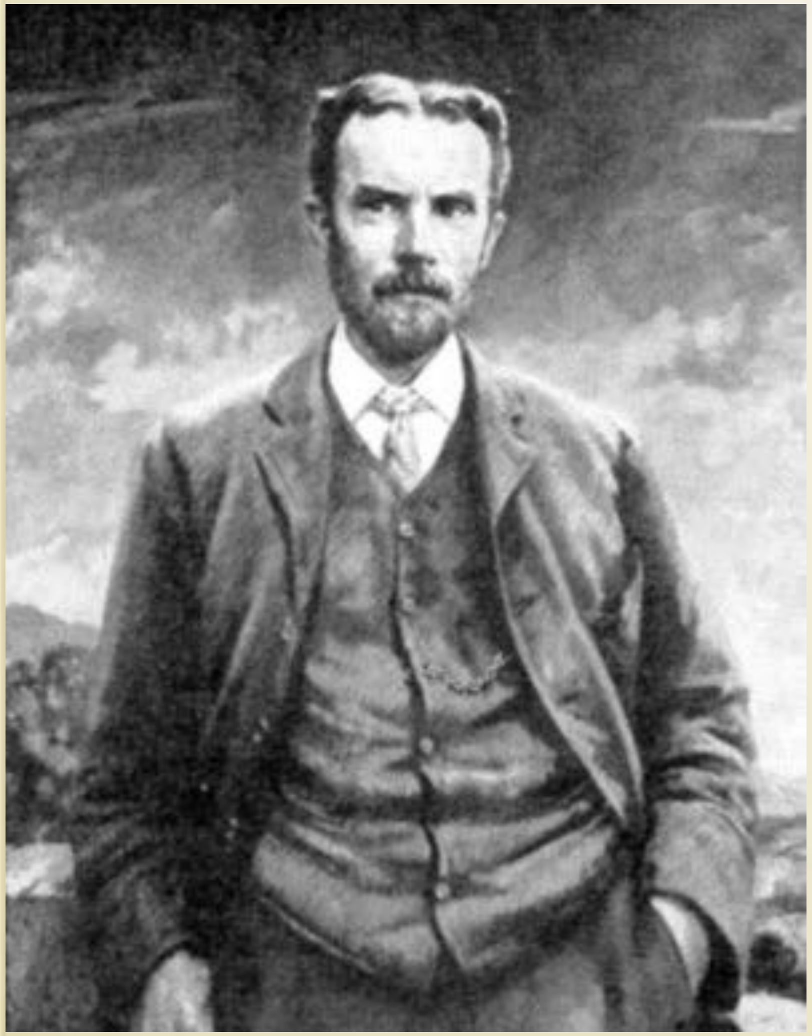
Guglielmo Marconi

Inventor of the radio telegraph system; first transatlantic radio transmission on
12 December 1901
at 820 kHz.

(25 April 1874 - 20 July 1937)

Ionised Layer

Oliver Heaviside



(18 May 1850 – 3 February 1925)

Arthur E Kennelly

(17 December 1861 - 18 June 1939)

In 1902, Heaviside and Kennelly independently predicted an ionised layer in the upper atmosphere that would reflect radio waves.

Edward Appleton

Appleton and his colleagues were one of two teams to prove the existence of a reflecting layer at a height of about 100 km (E layer), soon followed by the discovery of the F layer at around 250 km.

(6 September 1892 – 21 April 1965)

Ionosonde

G Breit and M A Tuve, A radio method of estimating the height of the conducting layer, *Nature*, 116, p. 357, 1925.

Gregory Breit

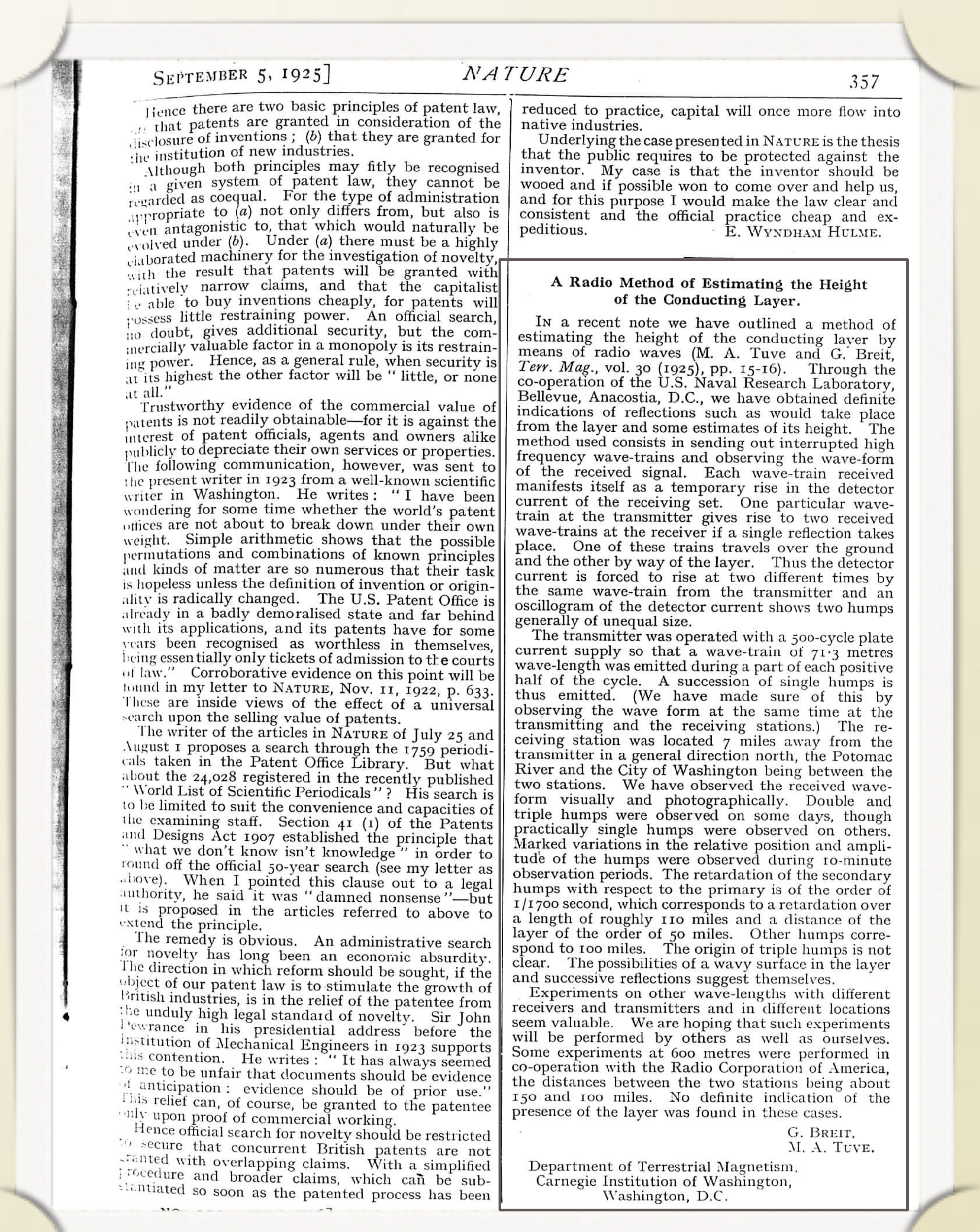
(14 July 1899 - 11 September 1981)

Merle Tuve

(27 June 1901 - 20 May 1982)

Birth of Ionosonde

G Breit and M A Tuve, A radio method of estimating the height of the conducting layer, *Nature*, 116, p. 357, 1925.



Hence there are two basic principles of patent law, (a) that patents are granted in consideration of the disclosure of inventions; (b) that they are granted for the institution of new industries.

Although both principles may fitly be recognised in a given system of patent law, they cannot be regarded as coequal. For the type of administration appropriate to (a) not only differs from, but also is even antagonistic to, that which would naturally be evolved under (b). Under (a) there must be a highly elaborated machinery for the investigation of novelty, with the result that patents will be granted with relatively narrow claims, and that the capitalist is able to buy inventions cheaply, for patents will possess little restraining power. An official search, no doubt, gives additional security, but the commercially valuable factor in a monopoly is its restraining power. Hence, as a general rule, when security is at its highest the other factor will be "little, or none at all."

Trustworthy evidence of the commercial value of patents is not readily obtainable—for it is against the interest of patent officials, agents and owners alike publicly to depreciate their own services or properties. The following communication, however, was sent to the present writer in 1923 from a well-known scientific writer in Washington. He writes: "I have been wondering for some time whether the world's patent offices are not about to break down under their own weight. Simple arithmetic shows that the possible permutations and combinations of known principles and kinds of matter are so numerous that their task is hopeless unless the definition of invention or originality is radically changed. The U.S. Patent Office is already in a badly demoralised state and far behind with its applications, and its patents have for some years been recognised as worthless in themselves, being essentially only tickets of admission to the courts of law." Corroborative evidence on this point will be found in my letter to NATURE, Nov. 11, 1922, p. 633. These are inside views of the effect of a universal search upon the selling value of patents.

The writer of the articles in NATURE of July 25 and August 1 proposes a search through the 1759 periodicals taken in the Patent Office Library. But what about the 24,028 registered in the recently published "World List of Scientific Periodicals"? His search is to be limited to suit the convenience and capacities of the examining staff. Section 41 (1) of the Patents and Designs Act 1907 established the principle that "what we don't know isn't knowledge" in order to round off the official 50-year search (see my letter as above). When I pointed this clause out to a legal authority, he said it was "damned nonsense"—but it is proposed in the articles referred to above to extend the principle.

The remedy is obvious. An administrative search for novelty has long been an economic absurdity. The direction in which reform should be sought, if the object of our patent law is to stimulate the growth of British industries, is in the relief of the patentee from the unduly high legal standard of novelty. Sir John Dewrance in his presidential address before the Institution of Mechanical Engineers in 1923 supports this contention. He writes: "It has always seemed to me to be unfair that documents should be evidence of anticipation: evidence should be of prior use." This relief can, of course, be granted to the patentee only upon proof of commercial working.

Hence official search for novelty should be restricted to secure that concurrent British patents are not granted with overlapping claims. With a simplified procedure and broader claims, which can be substantiated so soon as the patented process has been reduced to practice, capital will once more flow into native industries.

Underlying the case presented in NATURE is the thesis that the public requires to be protected against the inventor. My case is that the inventor should be wooed and if possible won to come over and help us, and for this purpose I would make the law clear and consistent and the official practice cheap and expeditious.

E. WYNDHAM HULME.

A Radio Method of Estimating the Height of the Conducting Layer.

IN a recent note we have outlined a method of estimating the height of the conducting layer by means of radio waves (M. A. Tuve and G. Breit, *Terr. Mag.*, vol. 30 (1925), pp. 15-16). Through the co-operation of the U.S. Naval Research Laboratory, Bellevue, Anacostia, D.C., we have obtained definite indications of reflections such as would take place from the layer and some estimates of its height. The method used consists in sending out interrupted high frequency wave-trains and observing the wave-form of the received signal. Each wave-train received manifests itself as a temporary rise in the detector current of the receiving set. One particular wave-train at the transmitter gives rise to two received wave-trains at the receiver if a single reflection takes place. One of these trains travels over the ground and the other by way of the layer. Thus the detector current is forced to rise at two different times by the same wave-train from the transmitter and an oscillogram of the detector current shows two humps generally of unequal size.

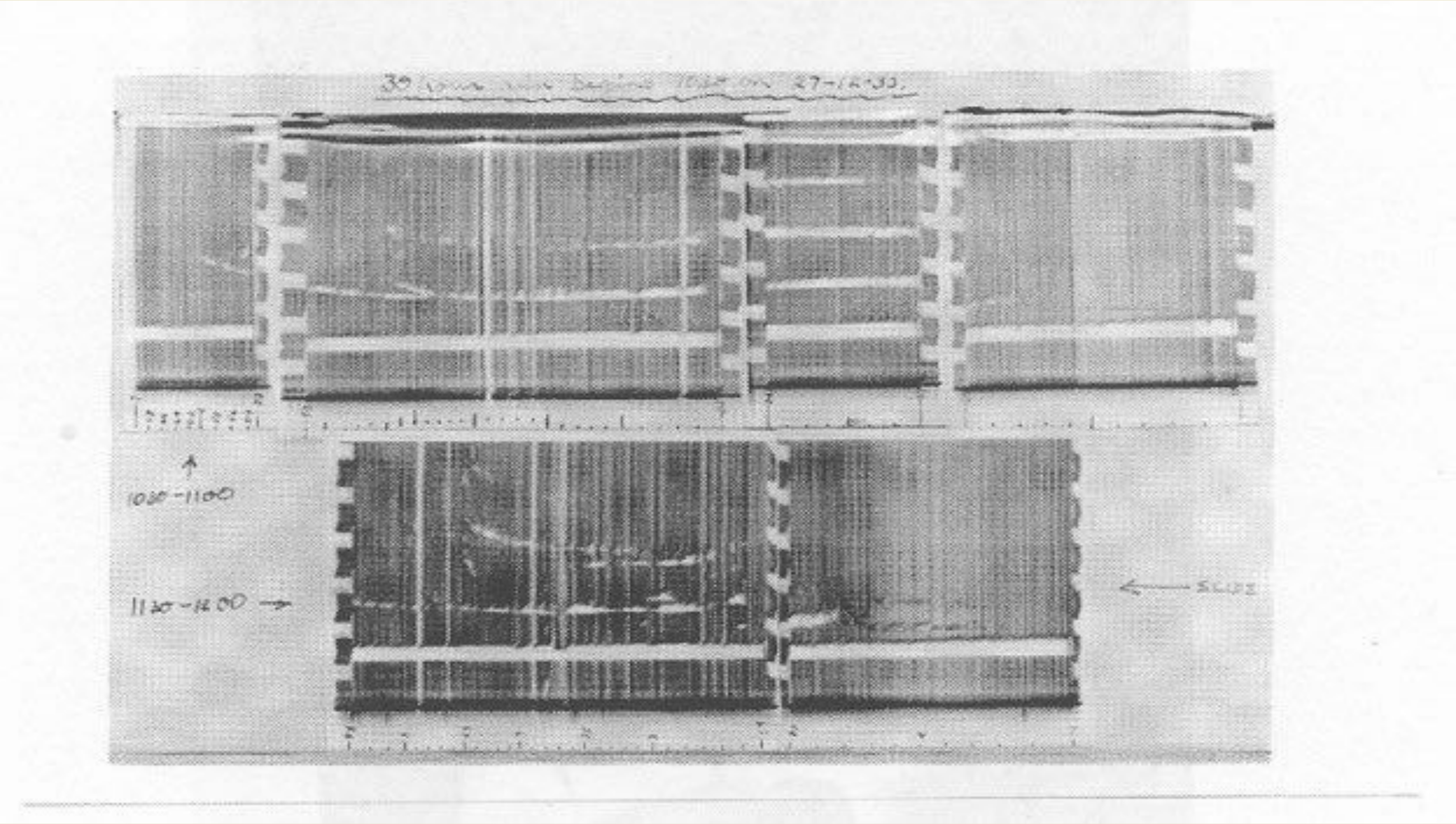
The transmitter was operated with a 500-cycle plate current supply so that a wave-train of 71·3 metres wave-length was emitted during a part of each positive half of the cycle. A succession of single humps is thus emitted. (We have made sure of this by observing the wave form at the same time at the transmitting and the receiving stations.) The receiving station was located 7 miles away from the transmitter in a general direction north, the Potomac River and the City of Washington being between the two stations. We have observed the received wave-form visually and photographically. Double and triple humps were observed on some days, though practically single humps were observed on others. Marked variations in the relative position and amplitude of the humps were observed during 10-minute observation periods. The retardation of the secondary humps with respect to the primary is of the order of 1/1700 second, which corresponds to a retardation over a length of roughly 110 miles and a distance of the layer of the order of 50 miles. Other humps correspond to 100 miles. The origin of triple humps is not clear. The possibilities of a wavy surface in the layer and successive reflections suggest themselves.

Experiments on other wave-lengths with different receivers and transmitters and in different locations seem valuable. We are hoping that such experiments will be performed by others as well as ourselves. Some experiments at 600 metres were performed in co-operation with the Radio Corporation of America, the distances between the two stations being about 150 and 100 miles. No definite indication of the presence of the layer was found in these cases.

G. BREIT.
M. A. TUVE.

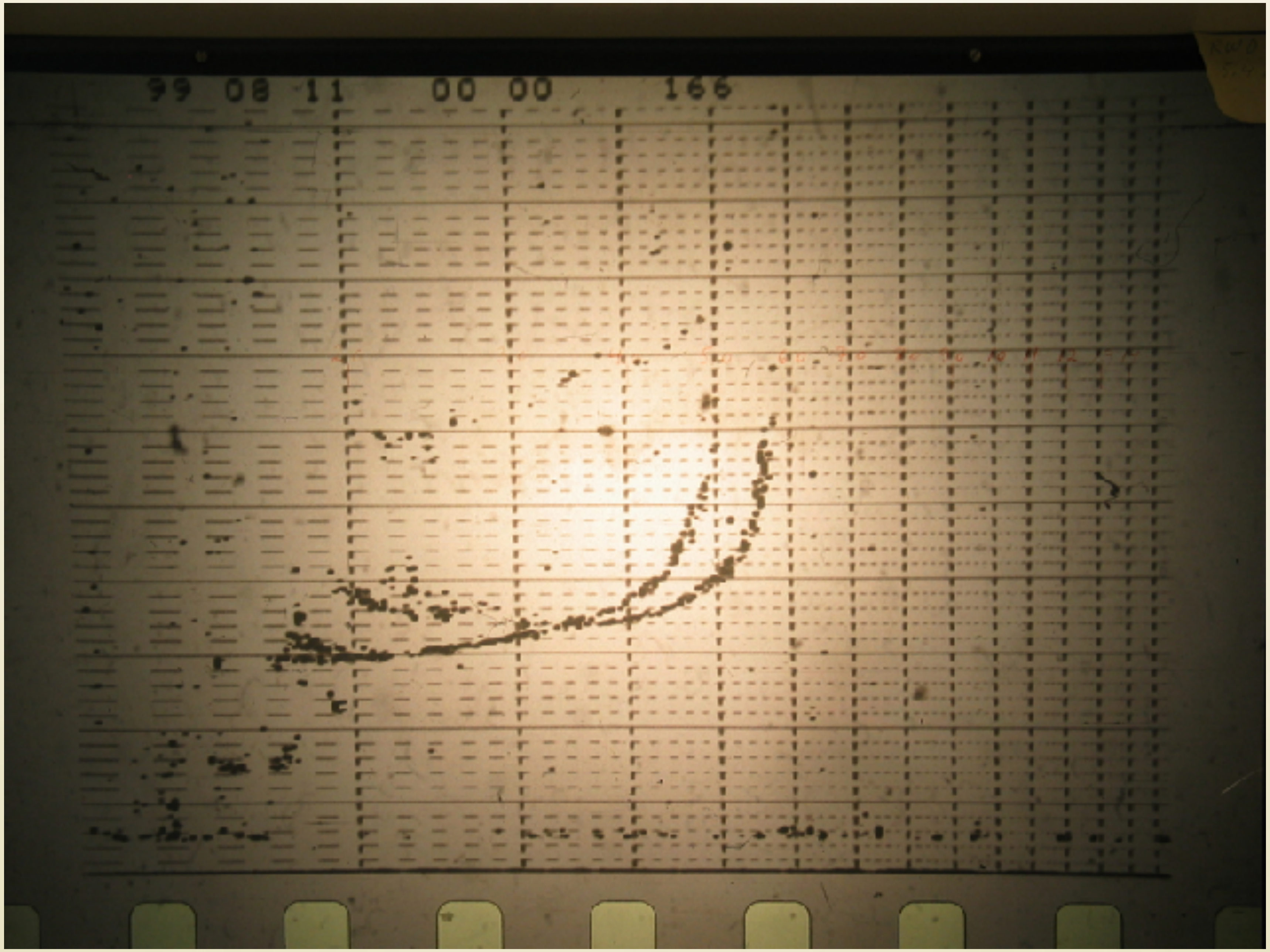
Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington, D.C.

Regular Ionograms



Radio Research Station Slough, Buckinghamshire
27th December 1933, 10:30-11:00 UTC and 11:30-12:00 UTC.

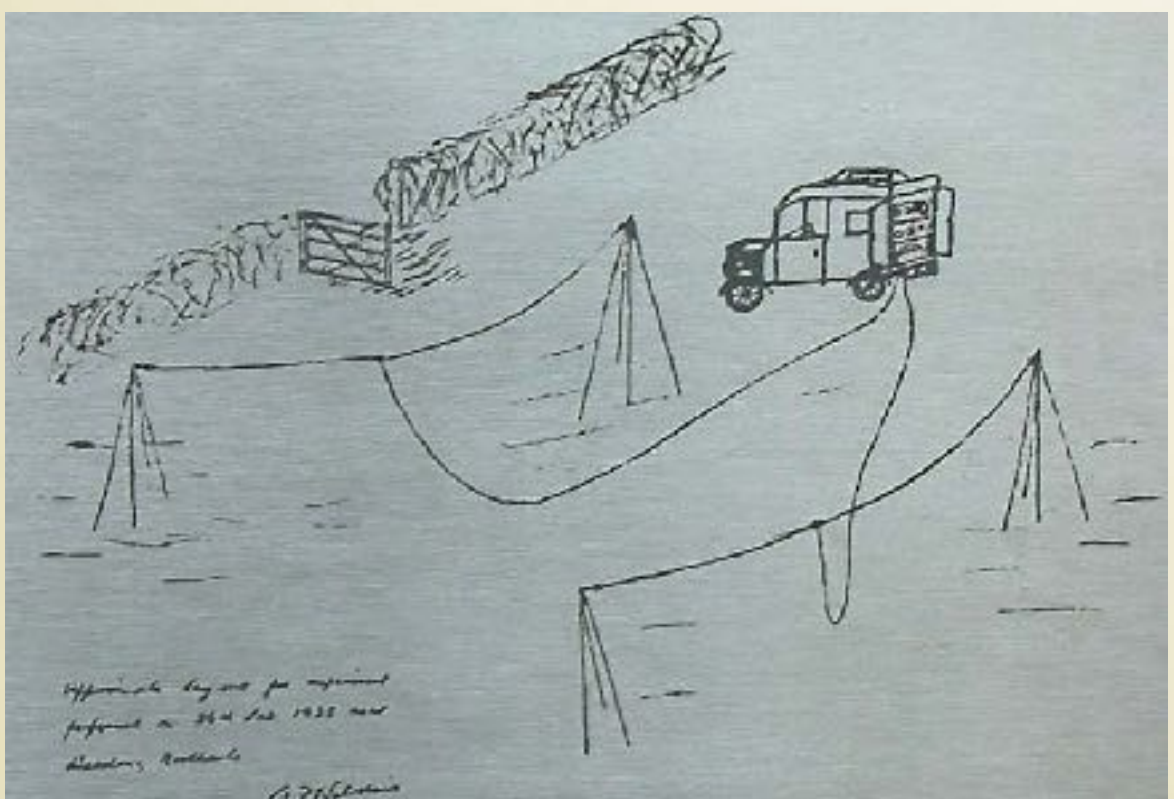
Sodankylä Ionosonde



(1 August 1957 – 15 November 2005)

Robert Watson-Watt

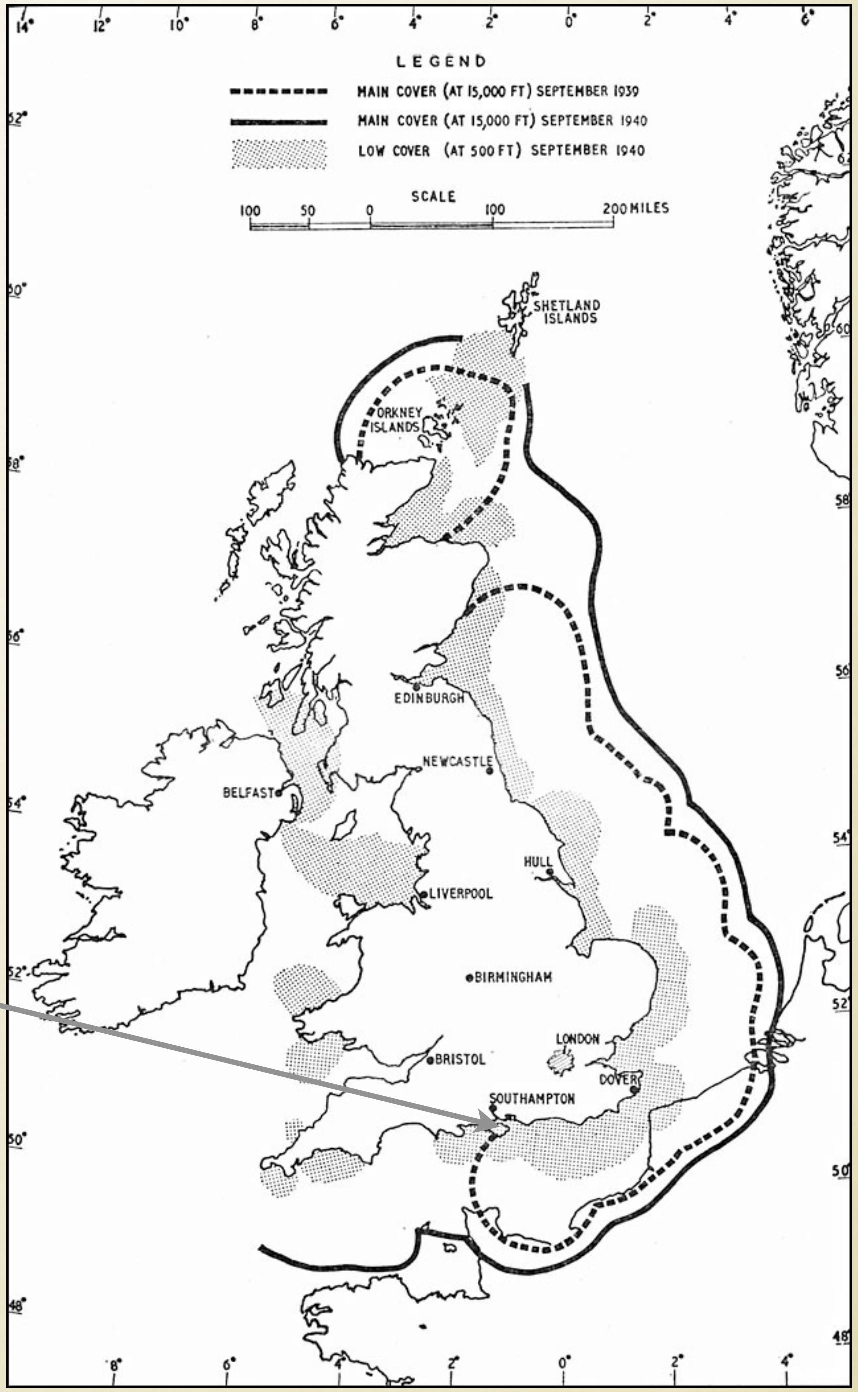
Daventry Experiment
26 Feb. 1935
patent for RADAR on 2 Apr. '35
June '35 detecting aircraft
at 27 km range.



(13 April 1892 – 5 December 1973)

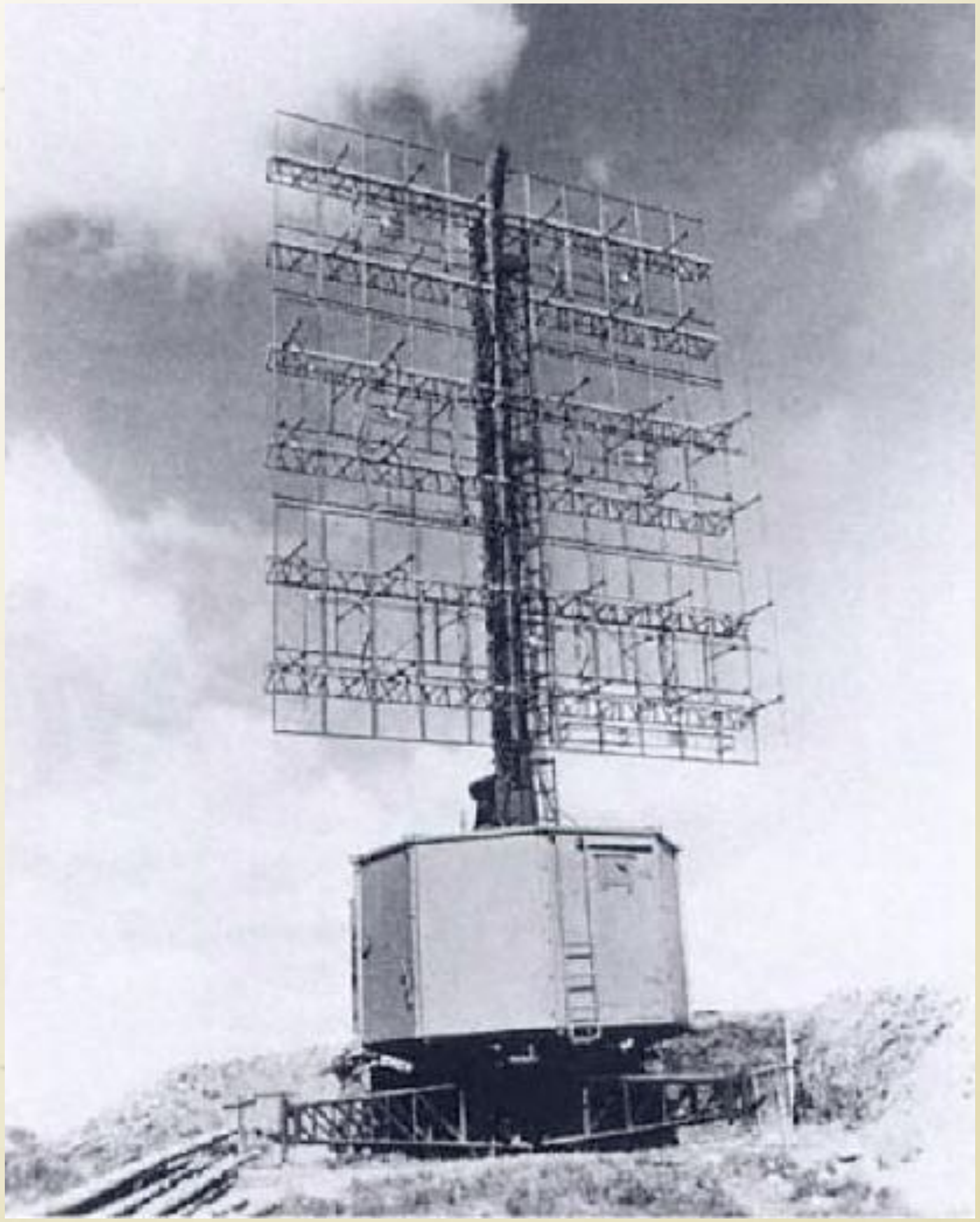
Chain Home

Multi-freq 12 m,
200 km range
CHlow 1.5 m



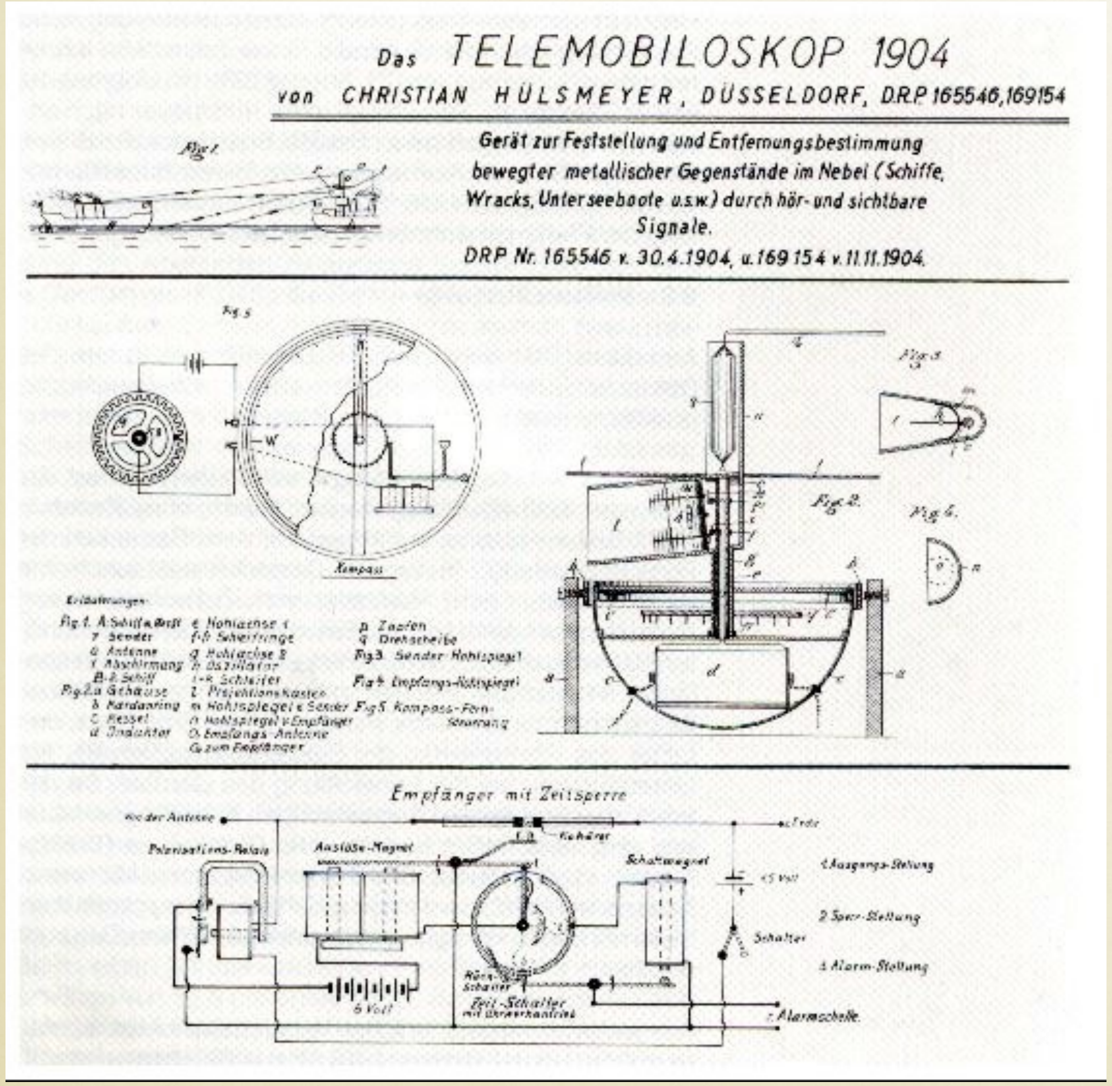
Freya

- German radar op. 1938.
- Portable(ish).
- 120-130 MHz (2.5-2.3 m).
- PRF 500 Hz, 3 μs pulses.
- Rotates 360°, 160 km range.
- Countermeasures:
  - Moonshine: re-emit amplified pulses (8 a/c = 100 bombers).
  - Jamming: 9 a/c create a 200-mile (320 km) gap.



Christian Hülsmeyer

Invented RADAR ...
... but no-one noticed.



(25 December 1881 - 31 January 1957)

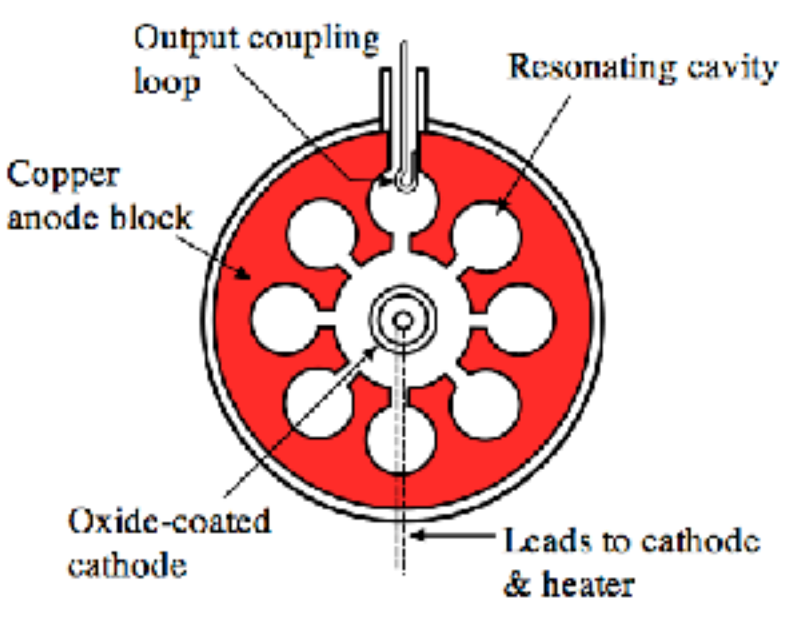
September 1939

More or less rudimentary but operational radars:

Britain, France, Germany, Hungary, Italy, Japan, the Netherlands, Russia, Switzerland, and the USA.

Cavity Magnetron

- Invented at U Birmingham, UK, by John Randall and Henry Boot.
- By mid-1940 cavity magnetron developed into a small, light-weight transmitter (3 GHz at 15kW).
- 10x improvement over other radar.



Resonant cavity magnetron high-power high-frequency oscillator

Status after WWII

- RADAR had evolved from prototypes to a multitude of different systems.
- Microwave signal generation had become practical.
- Advances in aerials, transmitters, receivers, displays etc. led to wide-spread use in communications and radar applications.

ISR History

(and some SGO)

Bill Gordon conceives of incoherent scatter

1955 – 1960 – 1965 – 1970 – 1975 – 1980 – 1985 – 1990 – 1995 – 2000 – 2005 – 2010 – 2015 – 2020

IGY

Photos: SGO Archive.

Bill Gordon conceives of incoherent scatter

SGO Ionosonde built

1955 – 1960 – 1965 – 1970 – 1975 – 1980 – 1985 – 1990 – 1995 – 2000 – 2005 – 2010 – 2015 – 2020

IGY

Photo: Thomas Ulich.

Millstone built by MIT Lincoln Lab

Bill Gordon conceives of incoherent scatter

1955 – 1960 – 1965 – 1970 – 1975 – 1980 – 1985 – 1990 – 1995 – 2000 – 2005 – 2010 – 2015 – 2020

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IRIS Kilpisjärvi, U Lancaster; Photo: Thomas Ulich.

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Millstone built by MIT Lincoln Lab

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SGO
50th anniversary
start of riometry
start of neutron monitor

1955 – 1960 – 1965 – 1970 – 1975 – 1980 – 1985 – 1990 – 1995 – 2000 – 2005 – 2010 – 2015 – 2020

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DNA builds ISR Stanford

Stanford radar moved to Chatanika

Chatanika Radar moved to Greenland

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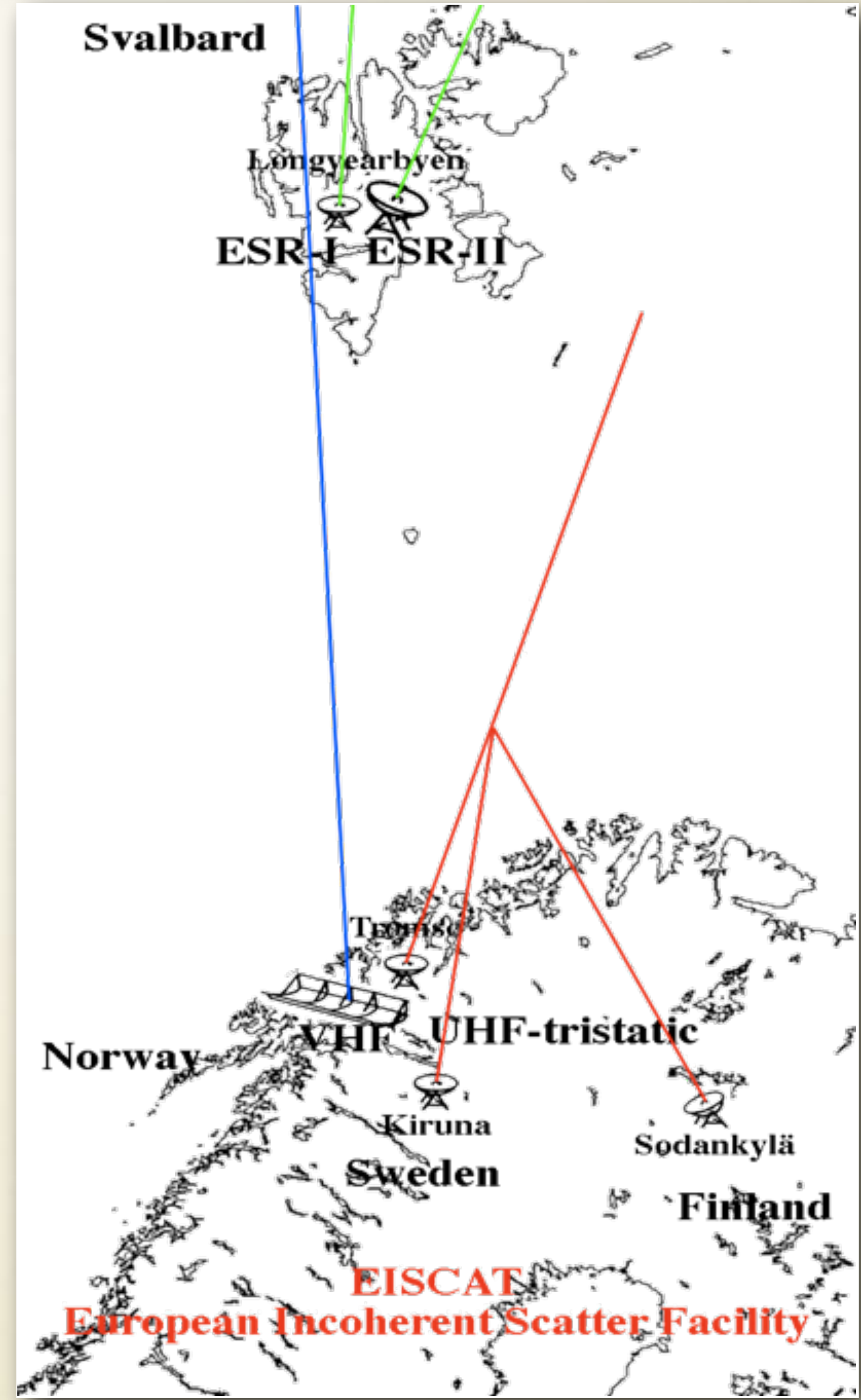
EISCAT SCIENTIFIC ASSOCIATION



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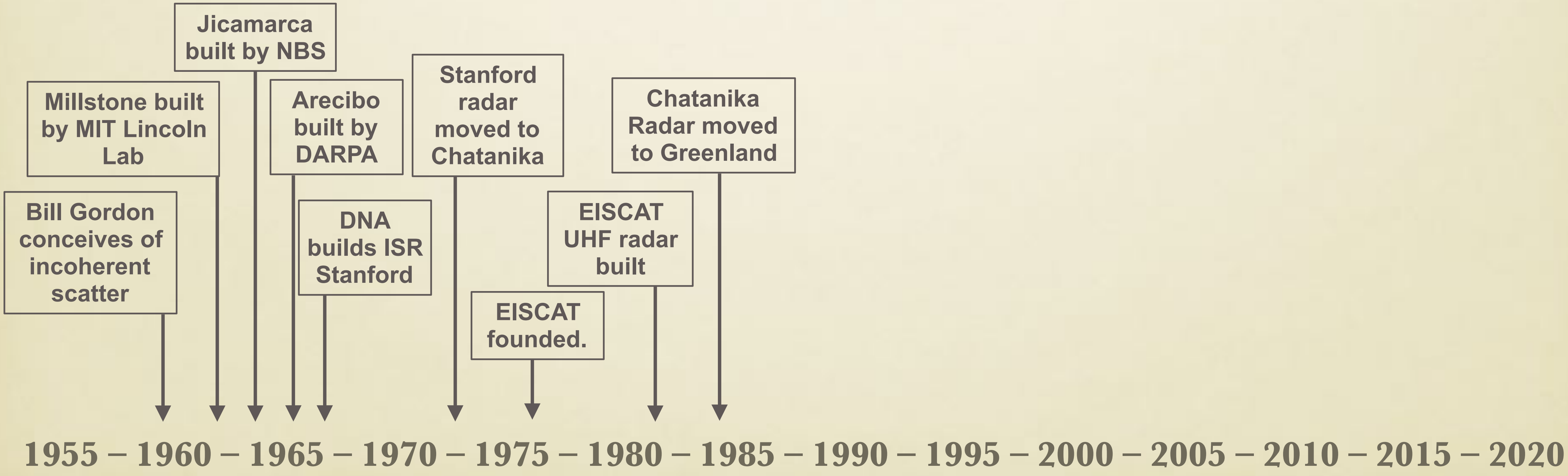
- DNA builds ISR Stanford
- Stanford radar moved to Chatanika
- EISCAT founded.
- Chatanika Radar moved to Greenland

1955 – 1960 – 1965 – 1970 – 1975 – 1980 – 1985 – 1990 – 1995 – 2000 – 2005 – 2010 – 2015 – 2020

Photo: Thomas Ulich.



Time-Lapse: Brian McClave.

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Stanford radar moved to Chatanika

EISCAT founded.

EISCAT UHF radar built

Chatanika Radar moved to Greenland

EISCAT VHF radar built

1955 – 1960 – 1965 – 1970 – 1975 – 1980 – 1985 – 1990 – 1995 – 2000 – 2005 – 2010 – 2015 – 2020

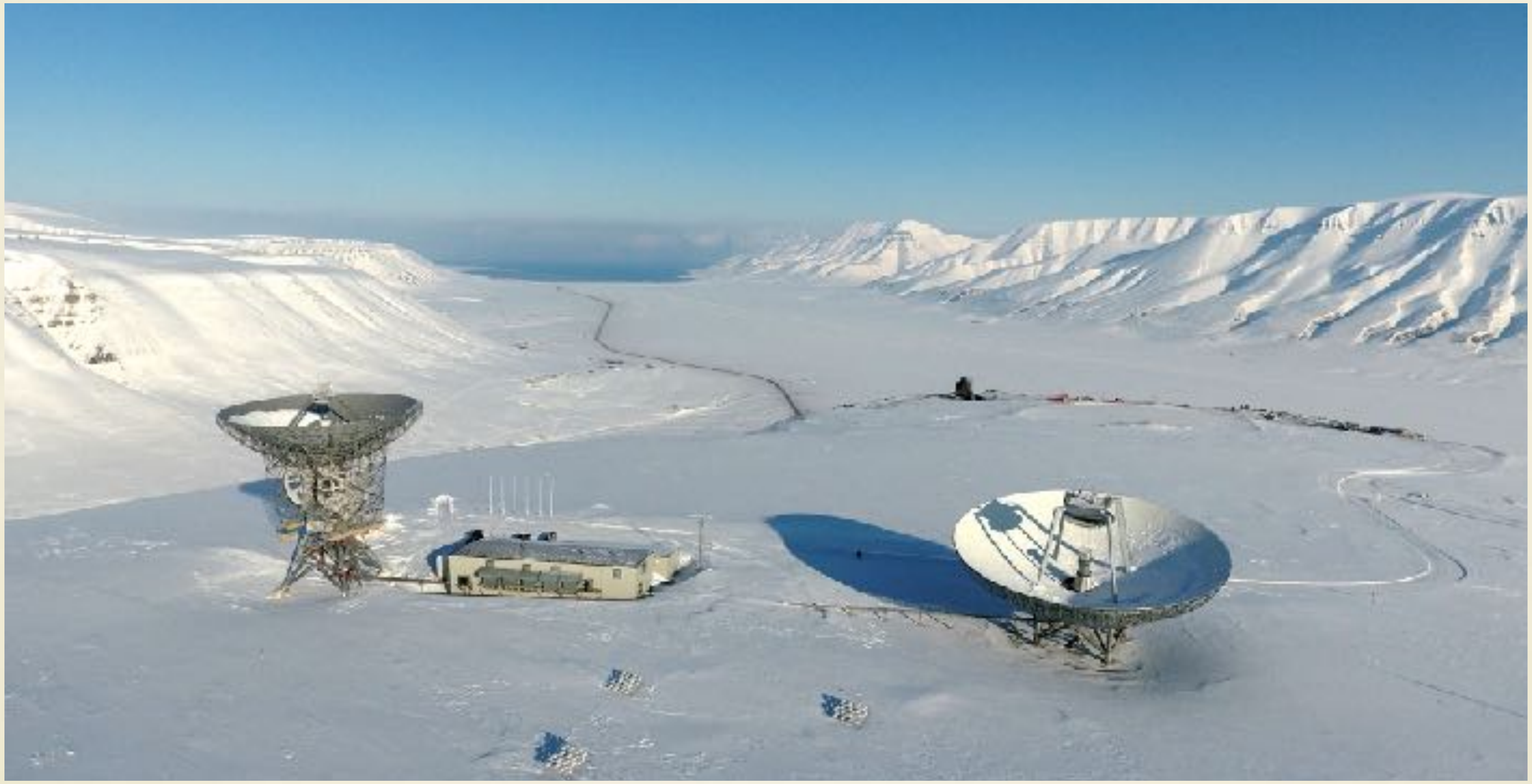
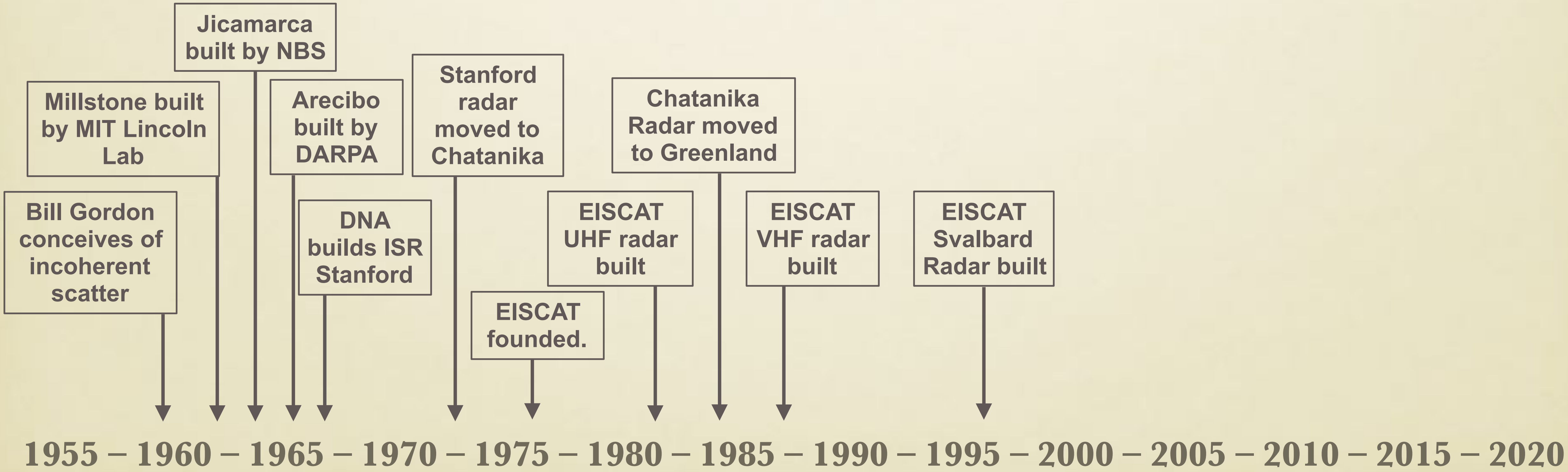
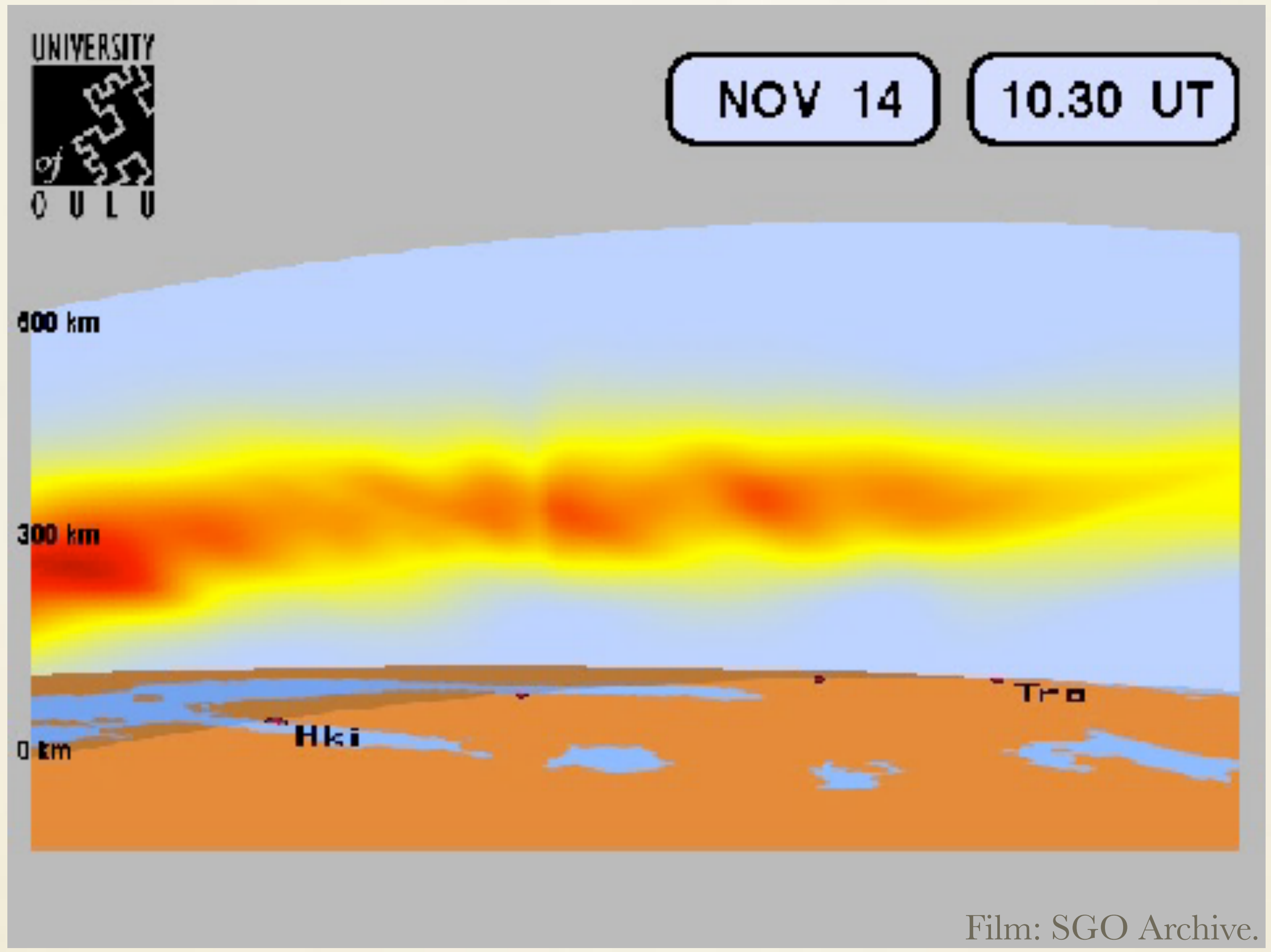
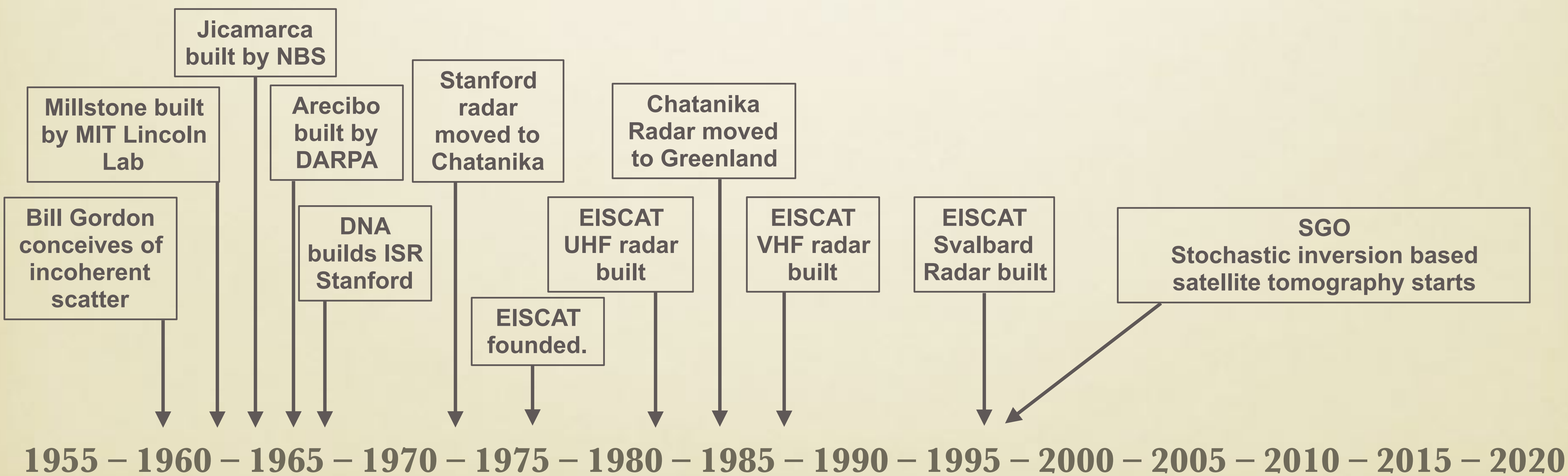


Photo: Craig Heinselman.

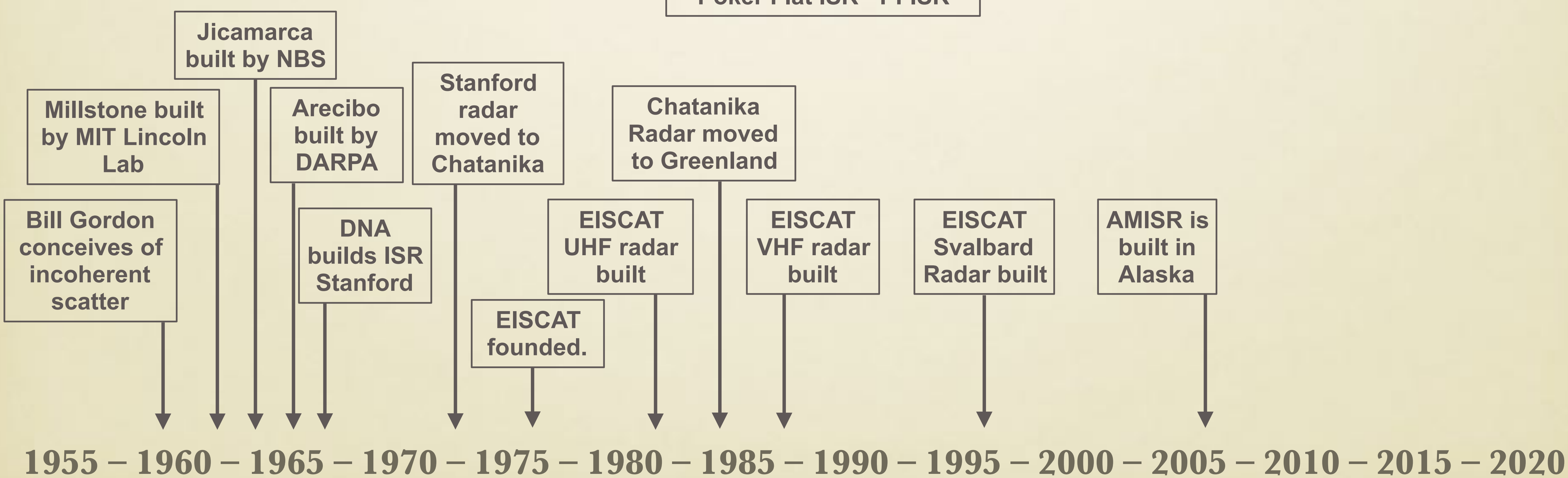


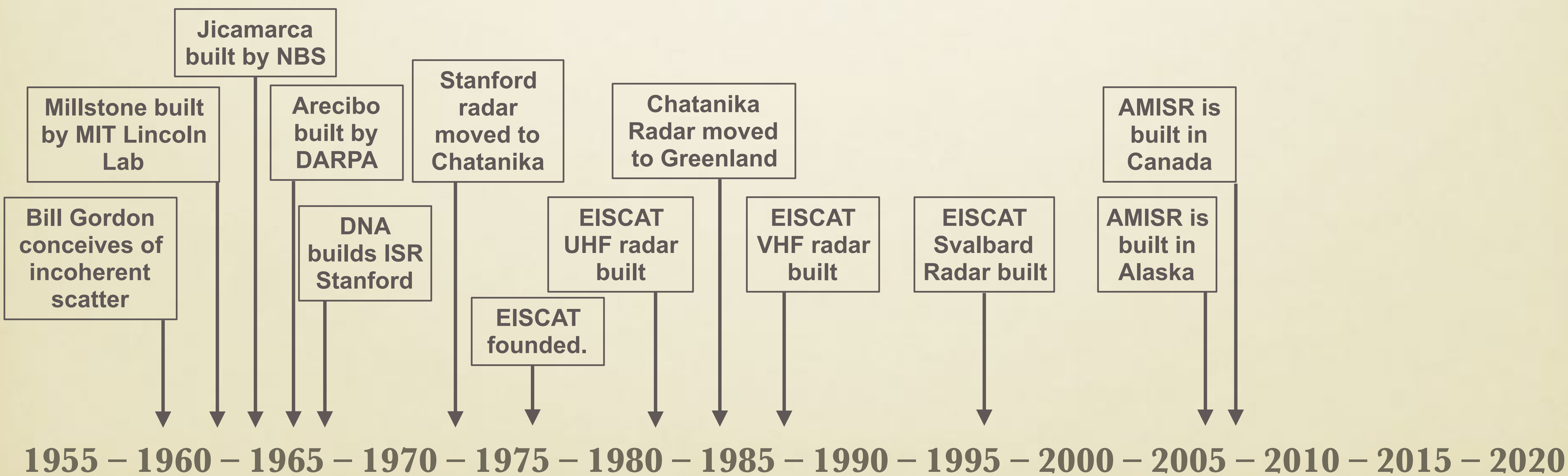


Film: SGO Archive.



Poker Flat ISR - PFISR

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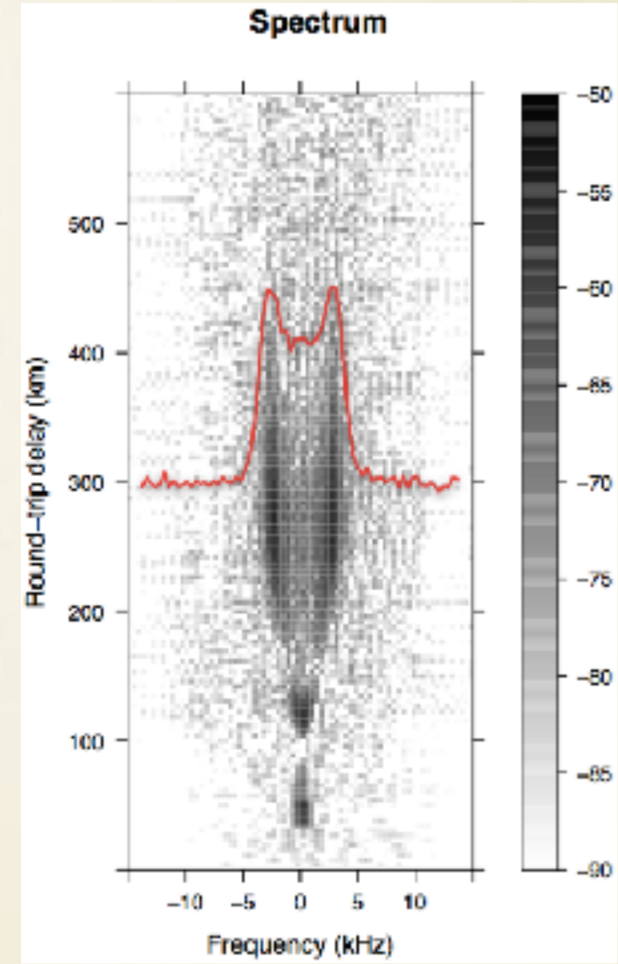
EISCAT Svalbard Radar built
AMISR is built in Alaska
AMISR is built in Canada
1955 – 1960 – 1965 – 1970 – 1975 – 1980 – 1985 – 1990 – 1995 – 2000 – 2005 – 2010 – 2015 – 2020



Time-Lapse: Brian McClave.

Courtesy: Juha Vierinen.

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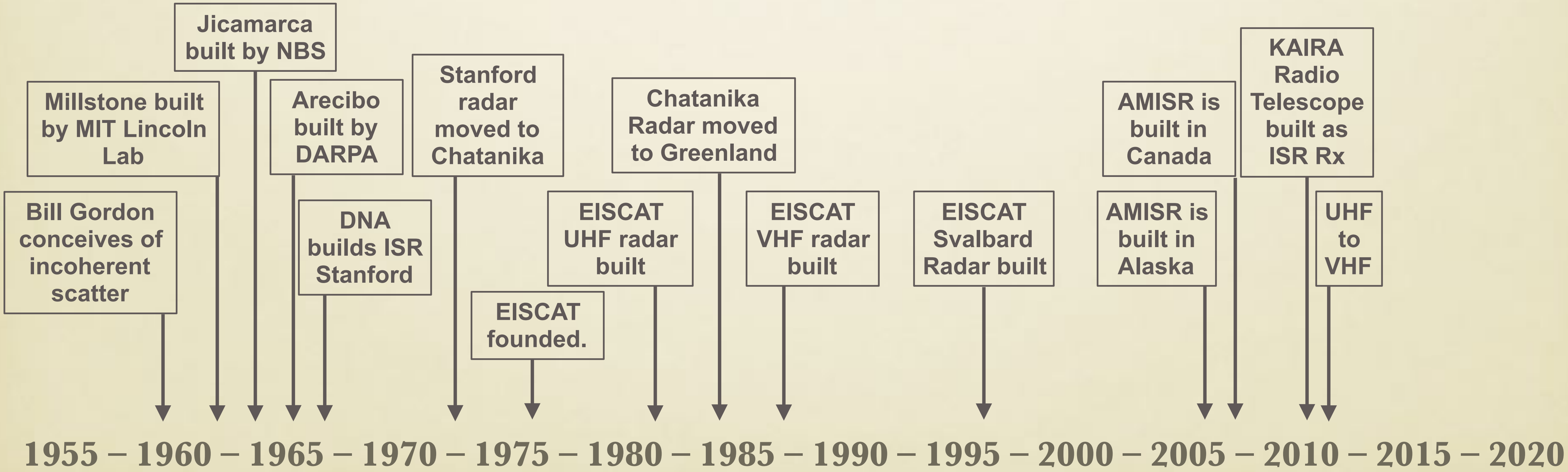
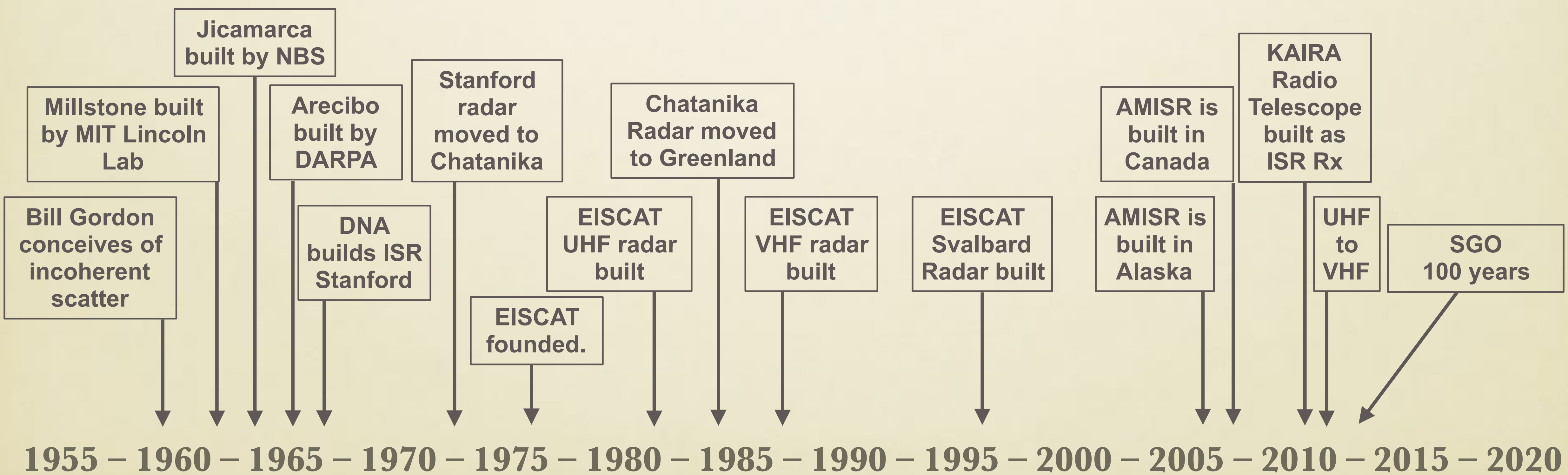
- EISCAT UHF radar built
- Chatanika Radar moved to Greenland
- EISCAT VHF radar built
- EISCAT Svalbard Radar built
- AMISR is built in Alaska
- AMISR is built in Canada
- KAIRA Radio Telescope built as ISR Rx

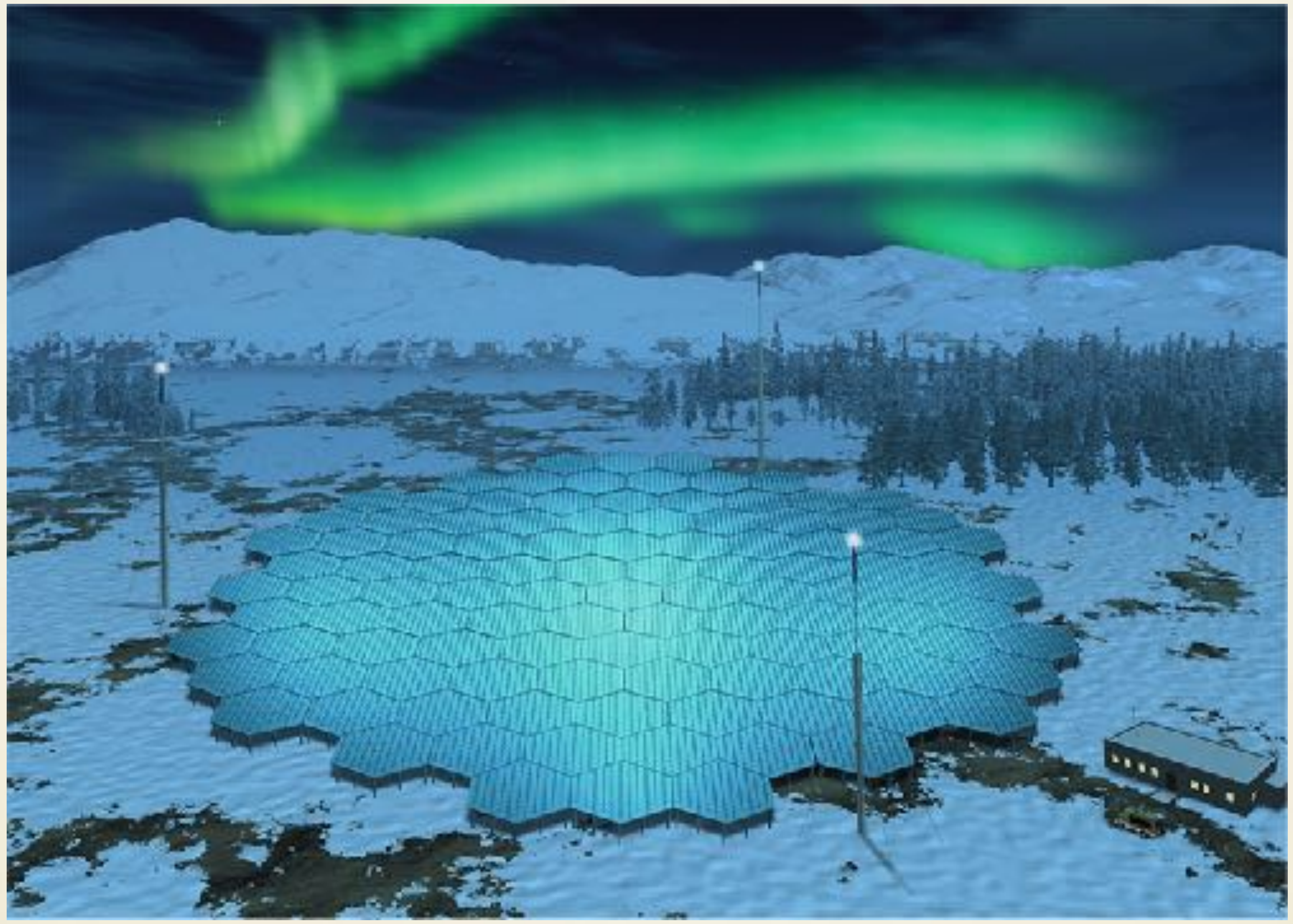
1955 – 1960 – 1965 – 1970 – 1975 – 1980 – 1985 – 1990 – 1995 – 2000 – 2005 – 2010 – 2015 – 2020

Photo: Thomas Ulich.



Photos: SGO Archive.





Graphic: ©NIPR, Tokyo, Japan.

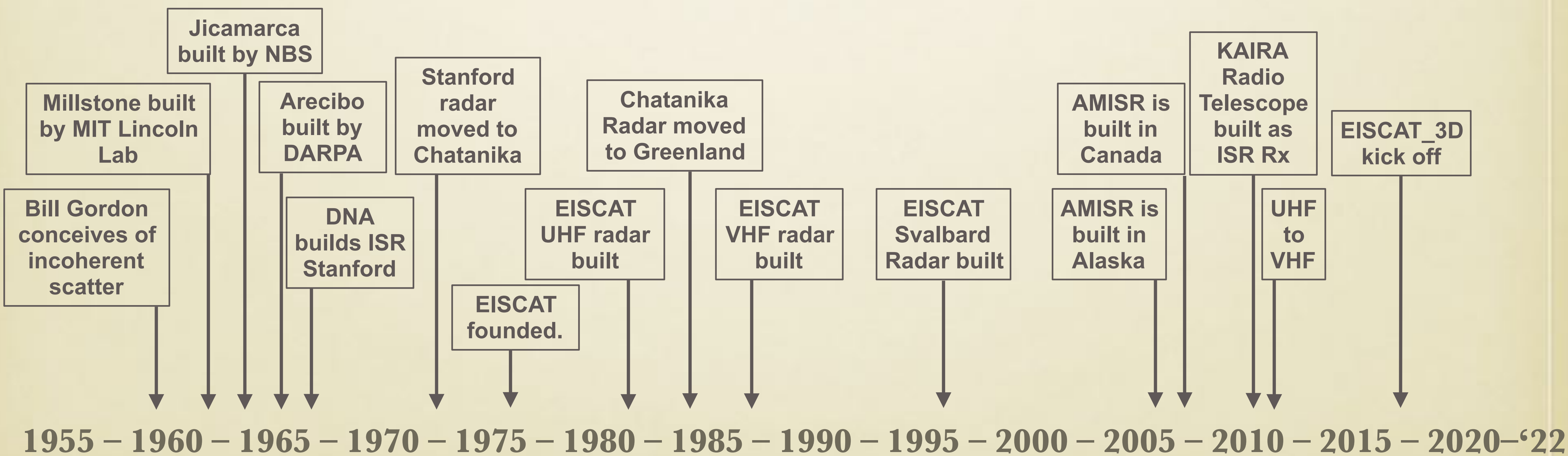
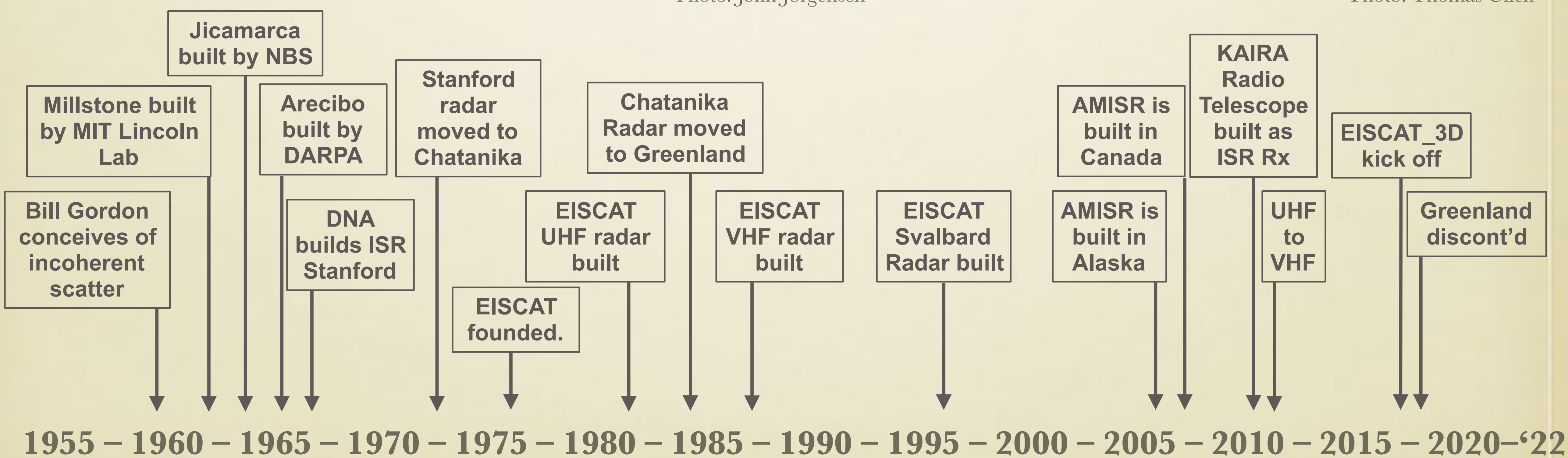
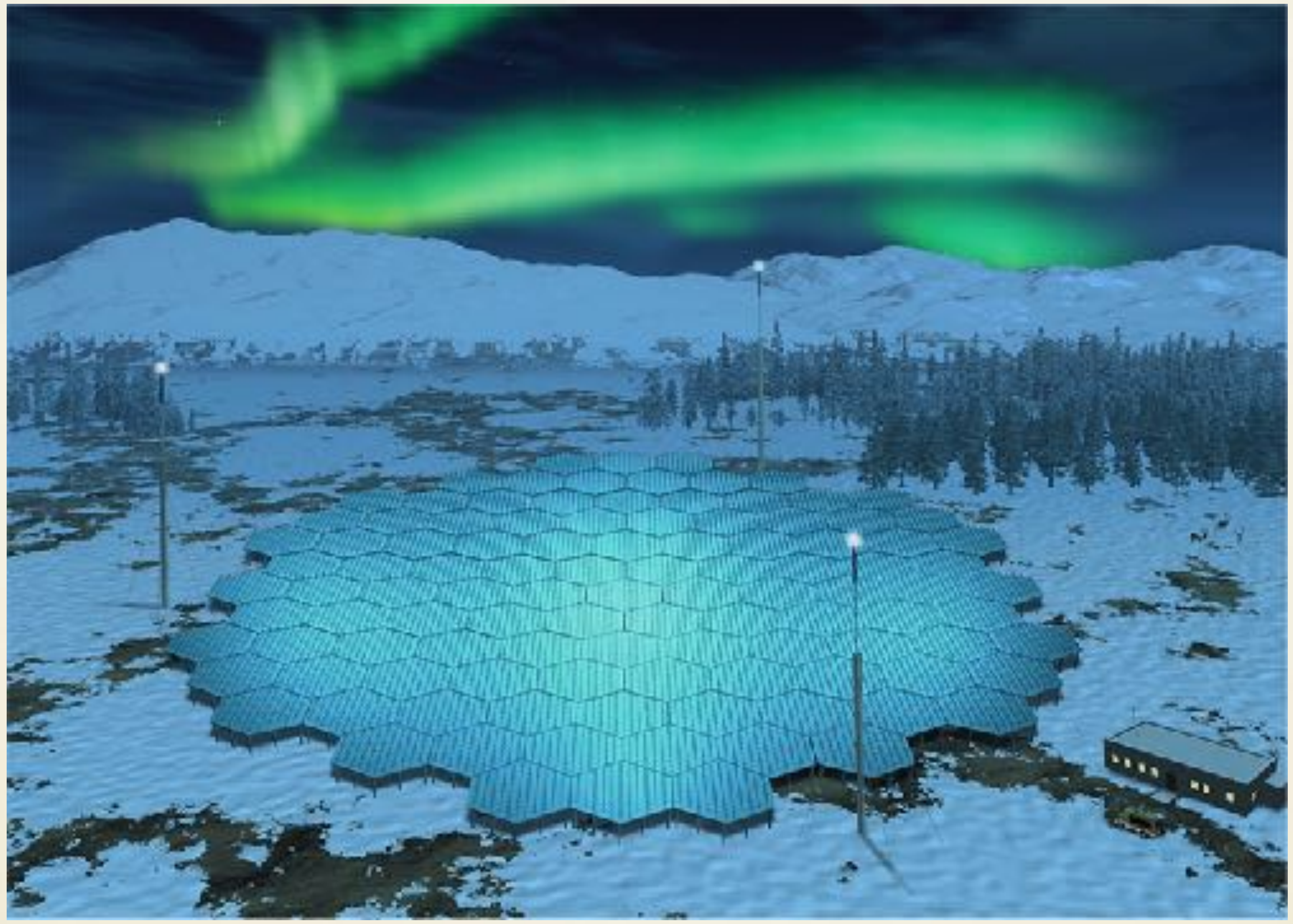


Photo: John Jørgensen

Photo: Thomas Ulich





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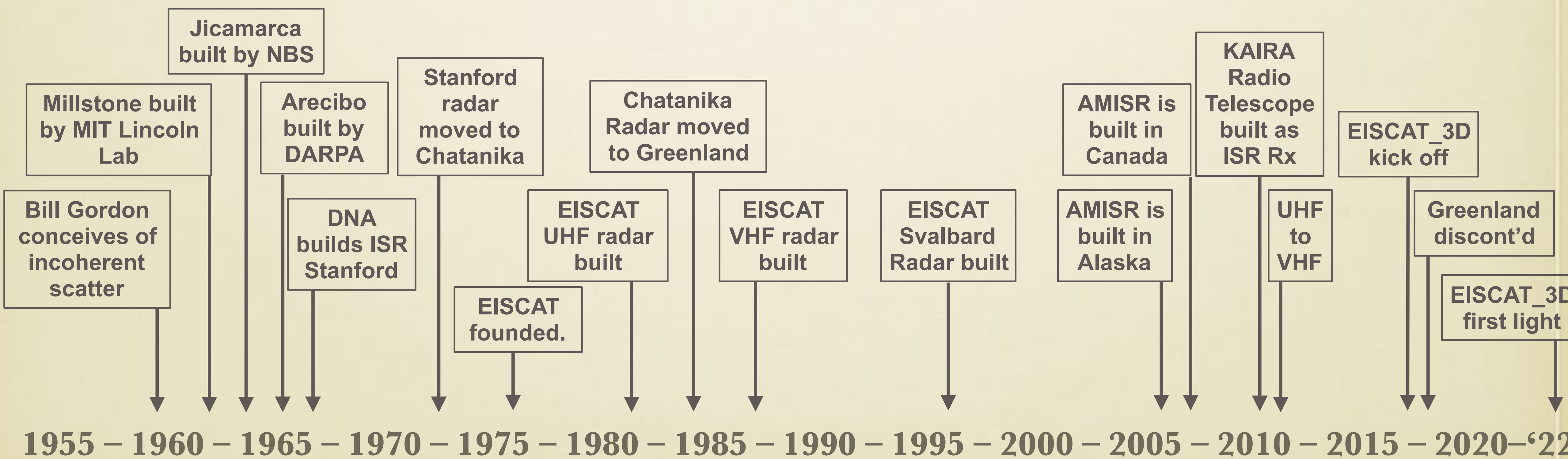

Thank you!