***Keynote*** *on the History of the Treaty Verification Regime*

# The GSE Story: Conceptual Development of the CTBT Verification System

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INGV

National Data Center

12 September 2025

# The GSE Story:
# Conceptual Development of the CTBT Verification System

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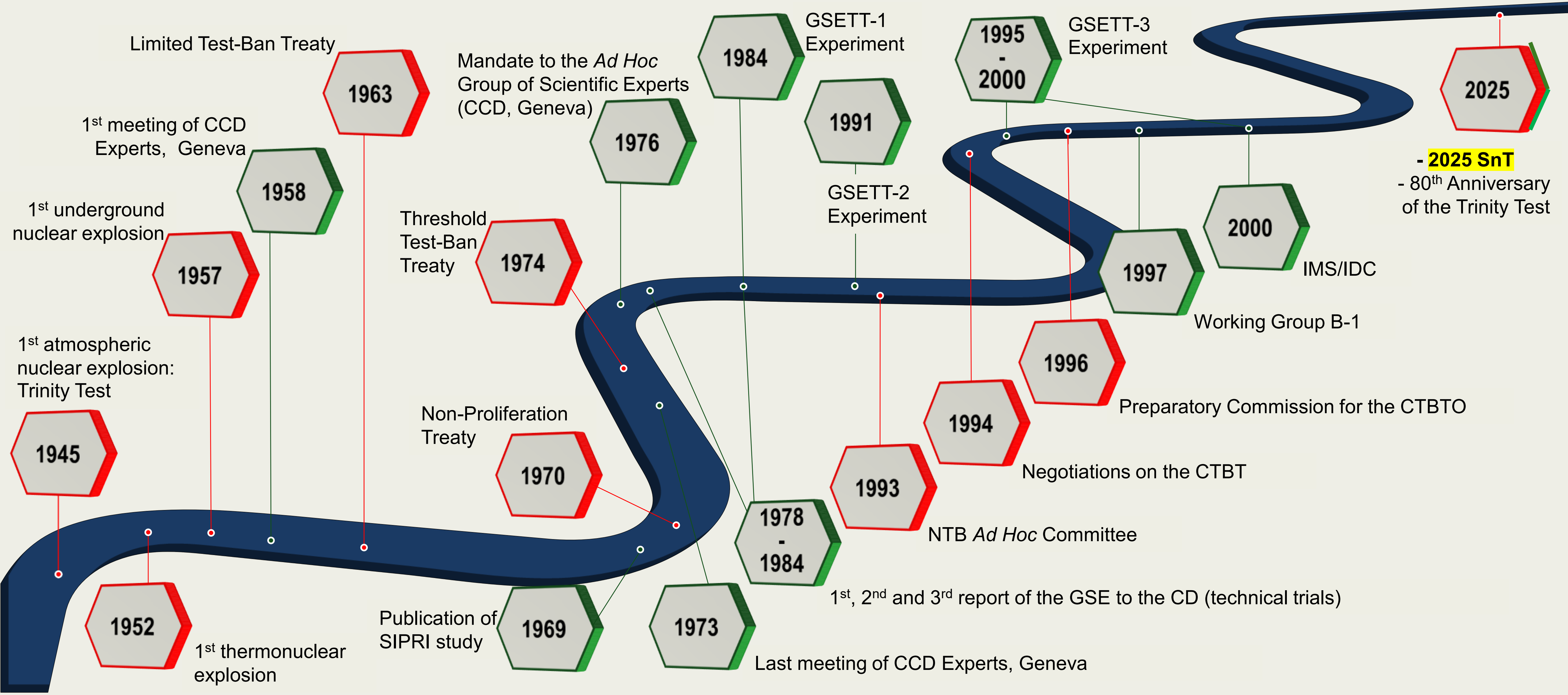
## History of Relevant Events Concerning Nuclear Explosions in Political and Scientific Context



# The Early Treatment of CTBT Verification

- Meetings of scientific experts in the frame of the **Conference of the Committee on Disarmament** (Geneva, 1958-1973).

The Council Chamber.
*(cc_jean-marc_ferre_1)*

The United Nations Office at Geneva.

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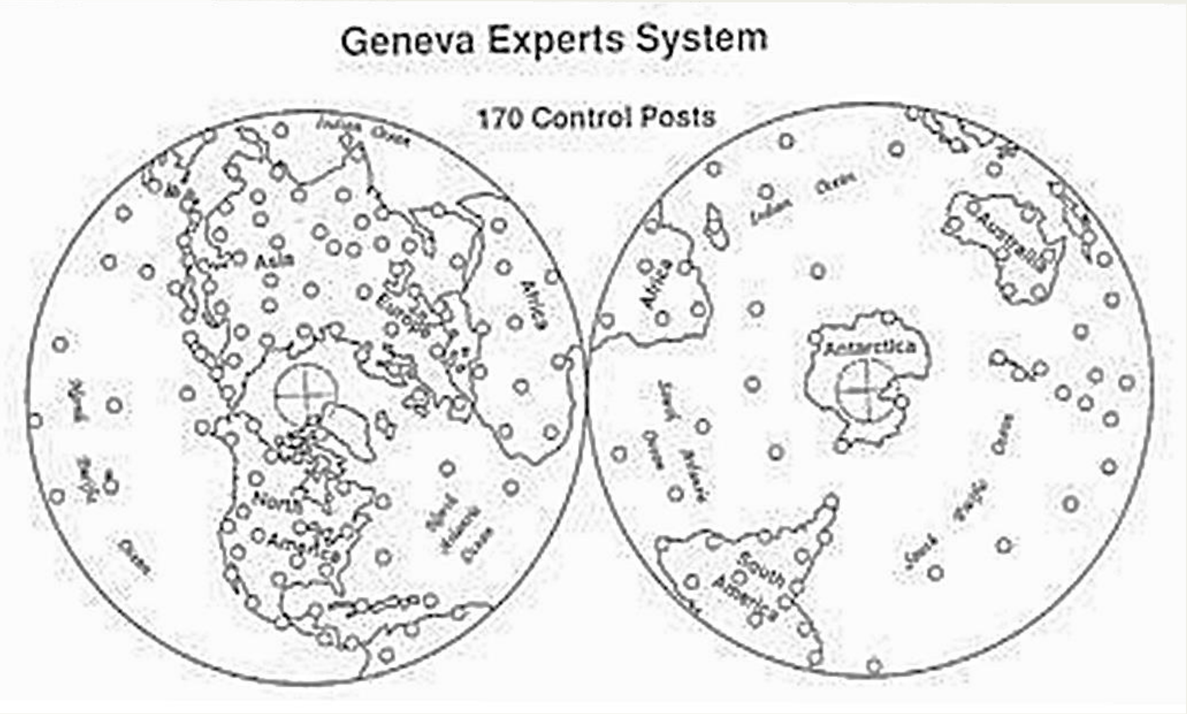
# The Early Treatment of CTBT Verification (continued)

**July 1958, the first Geneva Conference:**
The British delegation proposed a **system of 160 - 170 land-based control posts**, each operating a small array of about 10 seismic sensors: 100 to 110 based on continents, 20 on large islands, and 40 on small islands.

- Such a system would detect and identify 90% of the earthquakes equivalent to 5 kilotons or more, and a small percentage of those equivalent to one kiloton. The other 10% of 5 kt equivalent events would have to be inspected and estimates of the number of such events ranged from 20 per year (USSR estimate) to 100 per year (US estimate).

- The system was never built, but based on comparison with other networks, it appears that it would have enabled monitoring on a global basis of mb 3 rather than mb 4.




*(from Richards & Zavales, 1996)*

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# The 1969 SIPRI Specific Study

**1969:** The **Stockholm International Peace Research Institute** (SIPRI) published "Seismic Methods for Monitoring Underground Explosions“, a study by leading seismologists from ten countries, including four nuclear powers.

- This study provided a comprehensive assessment of seismic detection and identification of underground nuclear explosions, crucial for future negotiations on a comprehensive test ban.

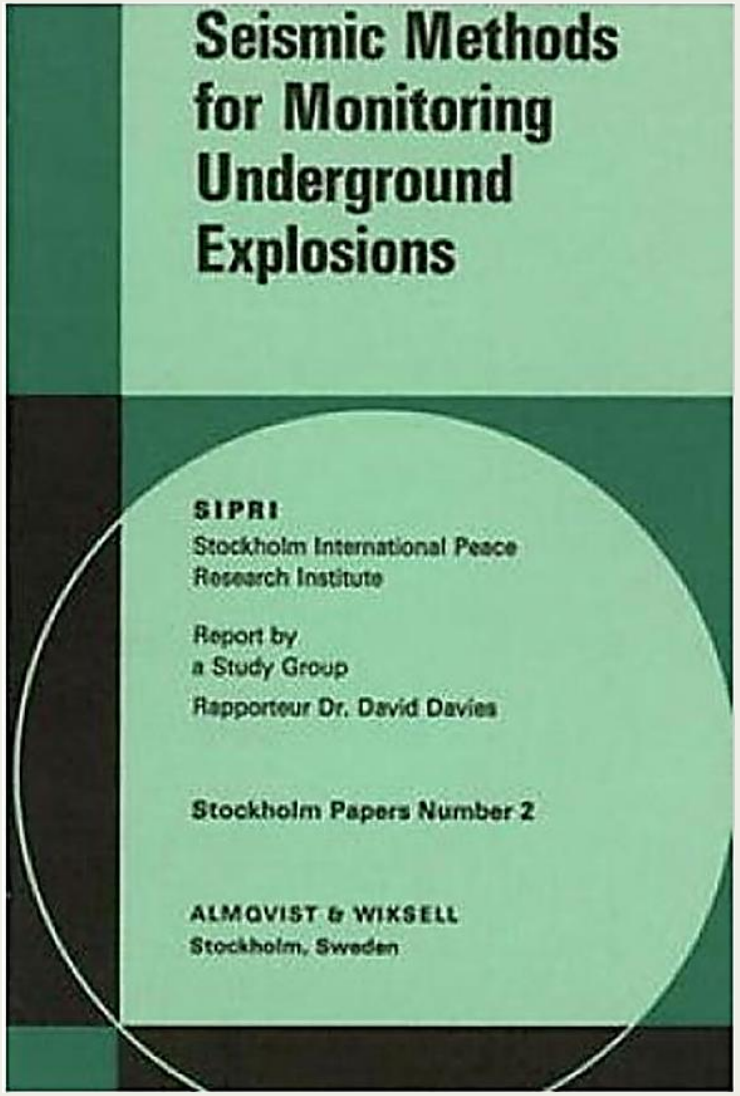
- It hypothesized a **global seismic network with approximately 50 to 100 high-quality seismic stations** to effectively monitor underground nuclear explosions.

- **Its Detection Capabilities:**

**Large-yield tests (≥10 kt)** → Easily detectable worldwide.

**Moderate-yield tests (≈1-10 kt)** → Detectable in most regions, depending on geological conditions.

**Low-yield tests (<1 kt)** → Detection was challenging, especially if decoupling techniques were used to muffle seismic signals.



# Final Steps in Preparation of the Group of Scientific Experts (Geneva, Spring 1976)

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- After the expert meeting of July 1973 at the CCD, two young researchers from the Swedish Defense Research Establishment, Hans Israelsson and Ola Dahlman, realized that ad hoc meetings wouldn't lead to concrete outcomes and concluded that a continuous process was needed.

- This process would have to involve a group of experts working together under the CCD's framework, with a clear mandate from political authorities and a consistent agenda (Dahlman *et al*., 2020).

- This idea was supported by many Delegations of the CCD, and some of them submitted national working papers on the subject of monitoring underground nuclear explosions:

**Sweden** - CCD/481, 26 March 1976, The Test Ban Issue.
**Sweden** - CCD/482, 26 March 1976, Working Paper on co-operative international measures to monitor a CTBT.

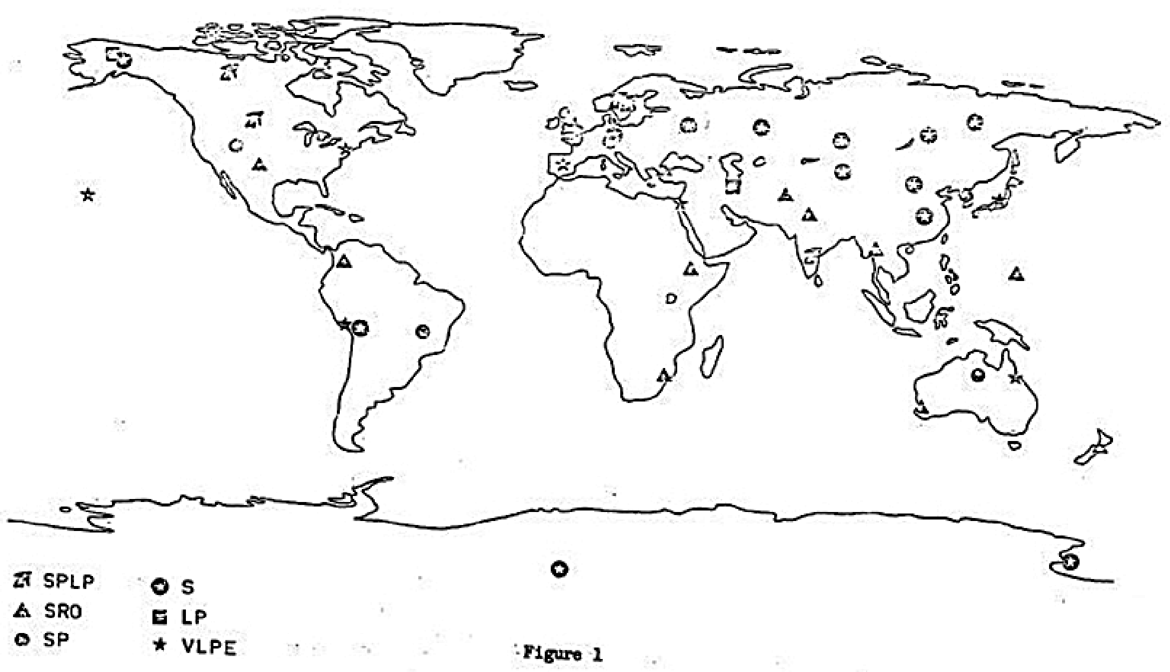


**Figure 1 of CD/482 - Seismic stations selected for the monitoring network example:**

**SPLP** = Array with short and long period systems

**SRO** = Seismological Research Observatory

**SP** = Array with short period system

**S** = Single station with short period system

**LP** = Array with long period system

**VLPE** = Very Long Period Experiment Station

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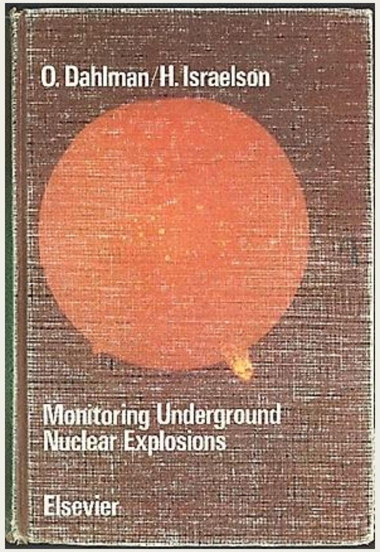
# The Seismic Network Considered by Dahlman and Israelson (1977)



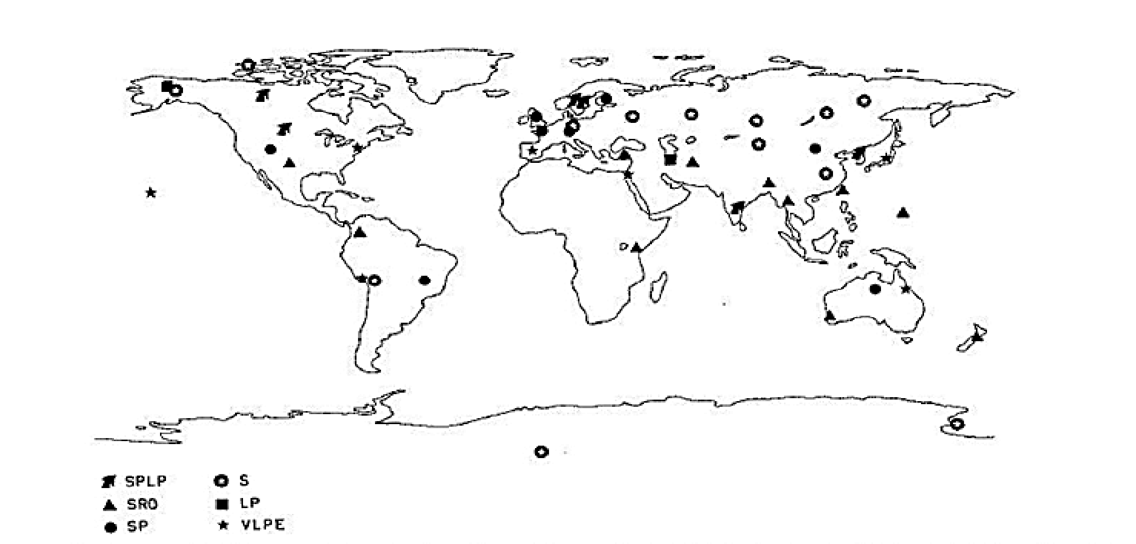




*Fig. 15.1. Geographical locations of the seismic stations of the monitoring network. SPLP = Array with short-period and long-period systems. SRO = Seismological Research Observatory. SP = Array with short-period system. S = Single station with short-period system. LP = Array with long-period system. VLPE = Very-Long-Period Experimental Station.*

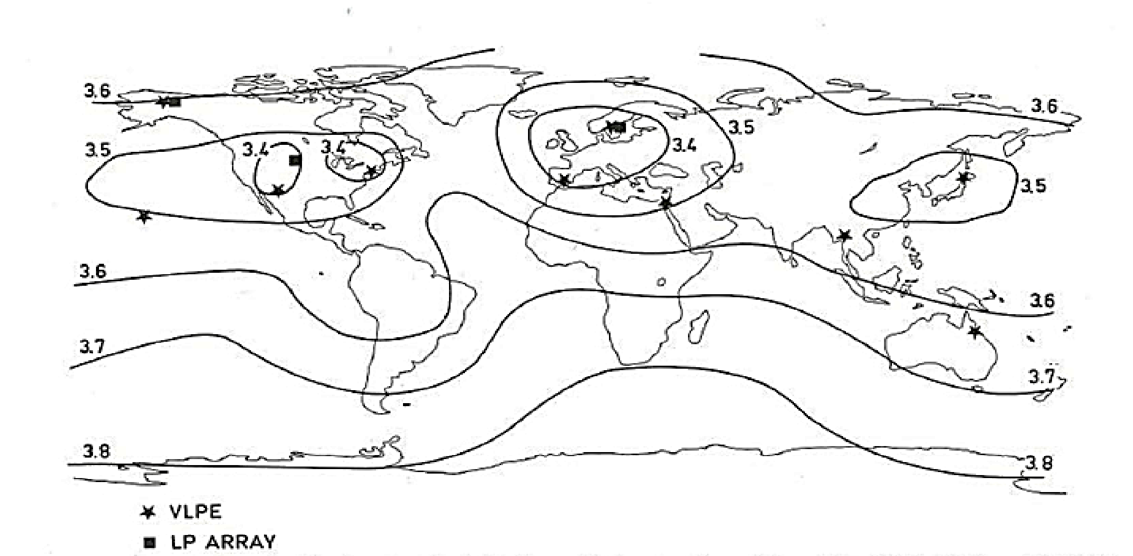



*Fig. 7.21. Long-period earthquake detection thresholds for a seismic network consisting of the ALPA, LASA, and NORSAR arrays and ten VLPE stations, as defined by ARPA (1973). The thresholds are given as the surface-wave magnitude, $M_s$, for which long-period signals of shallow earthquakes would be detected with 90 % probability by at least four stations in the network.*

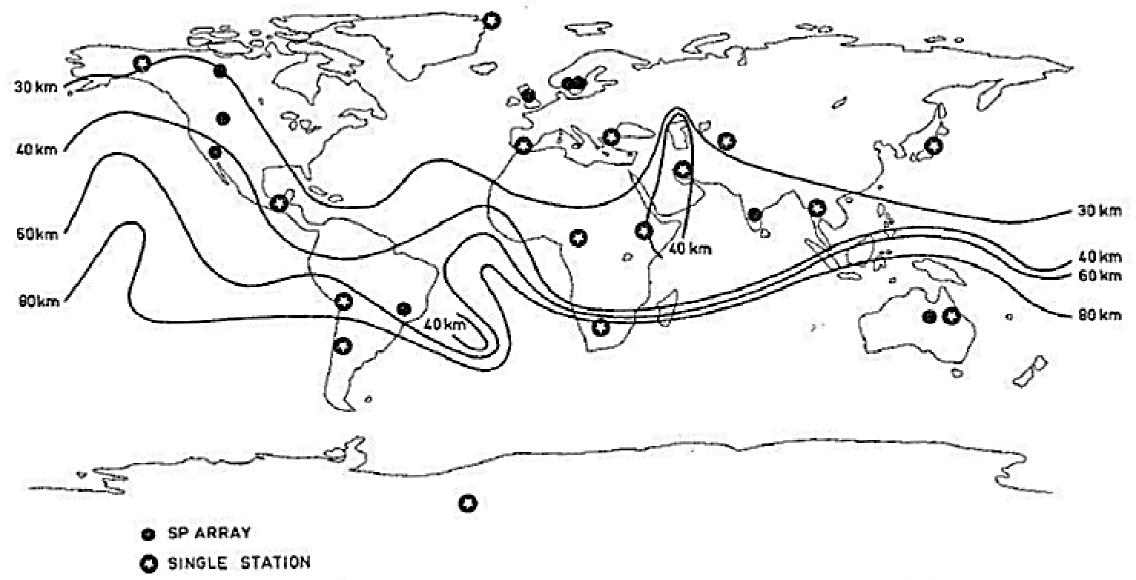



*Fig. 8.8. Estimated global location accuracy for magnitude-4.5 events located by a network of 25 high-sensitive stations.*

# The First Mandate of the CCD to the GSE

- **CCD decision of 22 July 1976:**

Established the ***Ad Hoc* Group of Scientific Experts (GSE)** to consider international co-operative measures to detect and to identify seismic events.

- The task assigned by the CCD to the GSE was to specify the characteristics of an **international monitoring system** based on the following three main pillars:

**(1)** A **global network of seismological stations**, selected from existing and planned installations.

**(2)** **Transmission facilities for the timely exchange of data** between seismological stations and data centres.

**(3)** **Facilities, procedures and related financial implications** with respect to contributing and receiving centres for detecting, locating and identifying seismic events throughout the world and facilitating the collation and dissemination of relevant documentation (Dahlman *et al*., 2020).

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# The First Mandate of the CCD to the GSE (continued)
# The Network

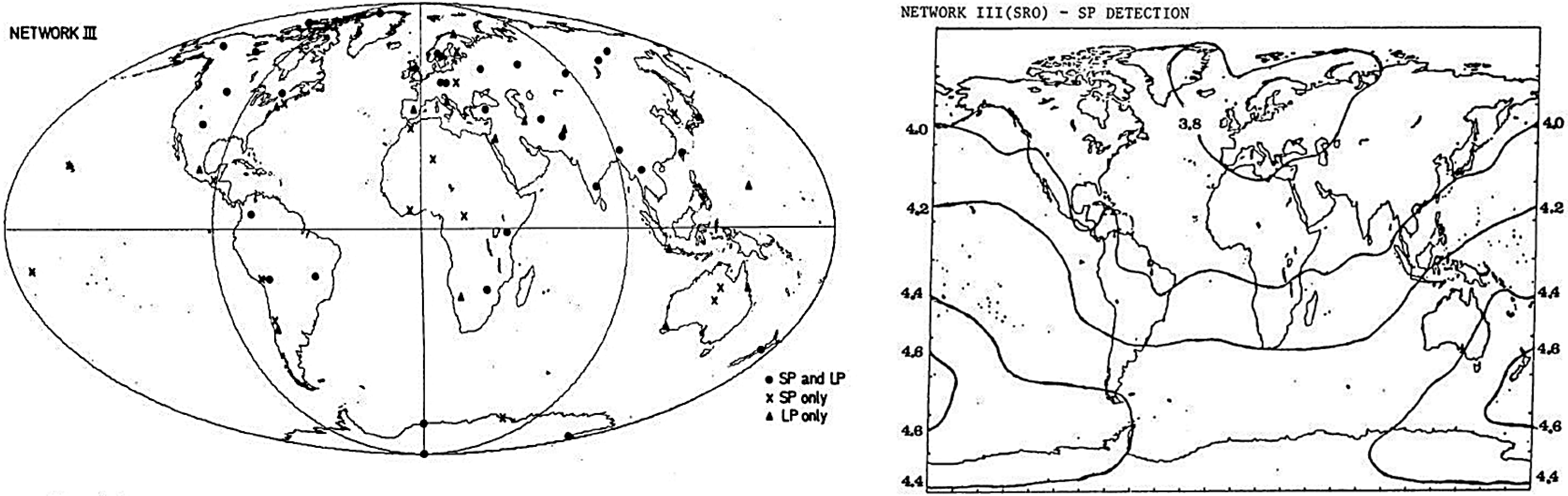


Figure 4.3 Map showing the location of stations in Network III and Network III (SRO).

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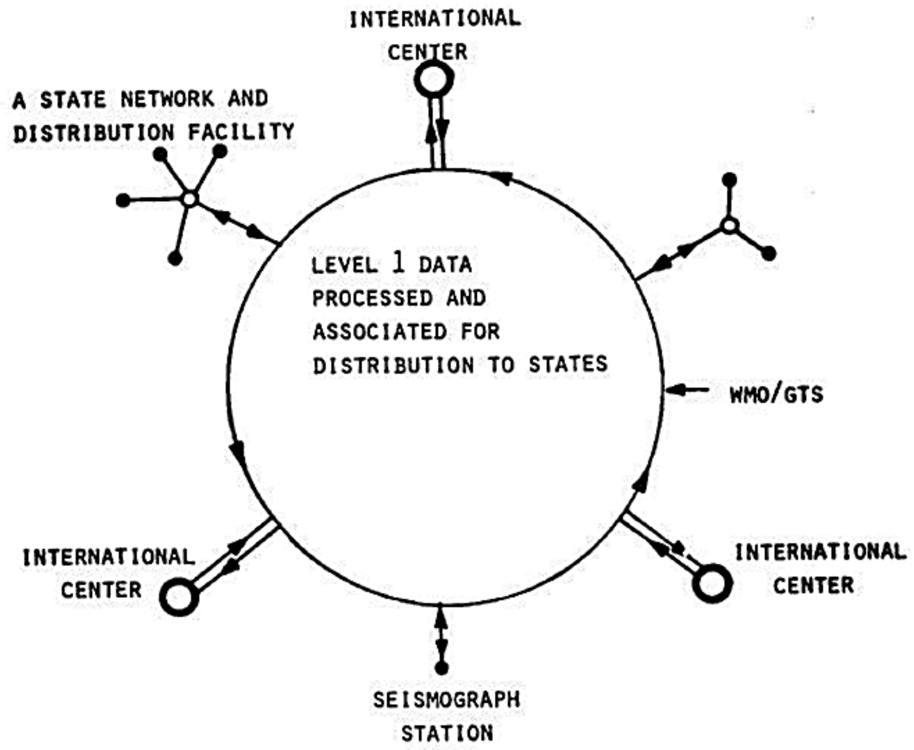
# The First Mandate of the CCD to the GSE (continued)
# The Concept of Data Communications




PURPOSE OF STATE FACILITY:

1) SENDS LEVEL 1 DATA
2) RECEIVES EPICENTERS AND ASSOCIATED IDENTIFICATION PARAMETERS
3) SENDS AND RECEIVES LEVEL 2 DATA ON REQUEST.

A SINGLE STATION WHEN OFFICIALLY AUTHORIZED HAS SIMILAR COMMITMENTS.

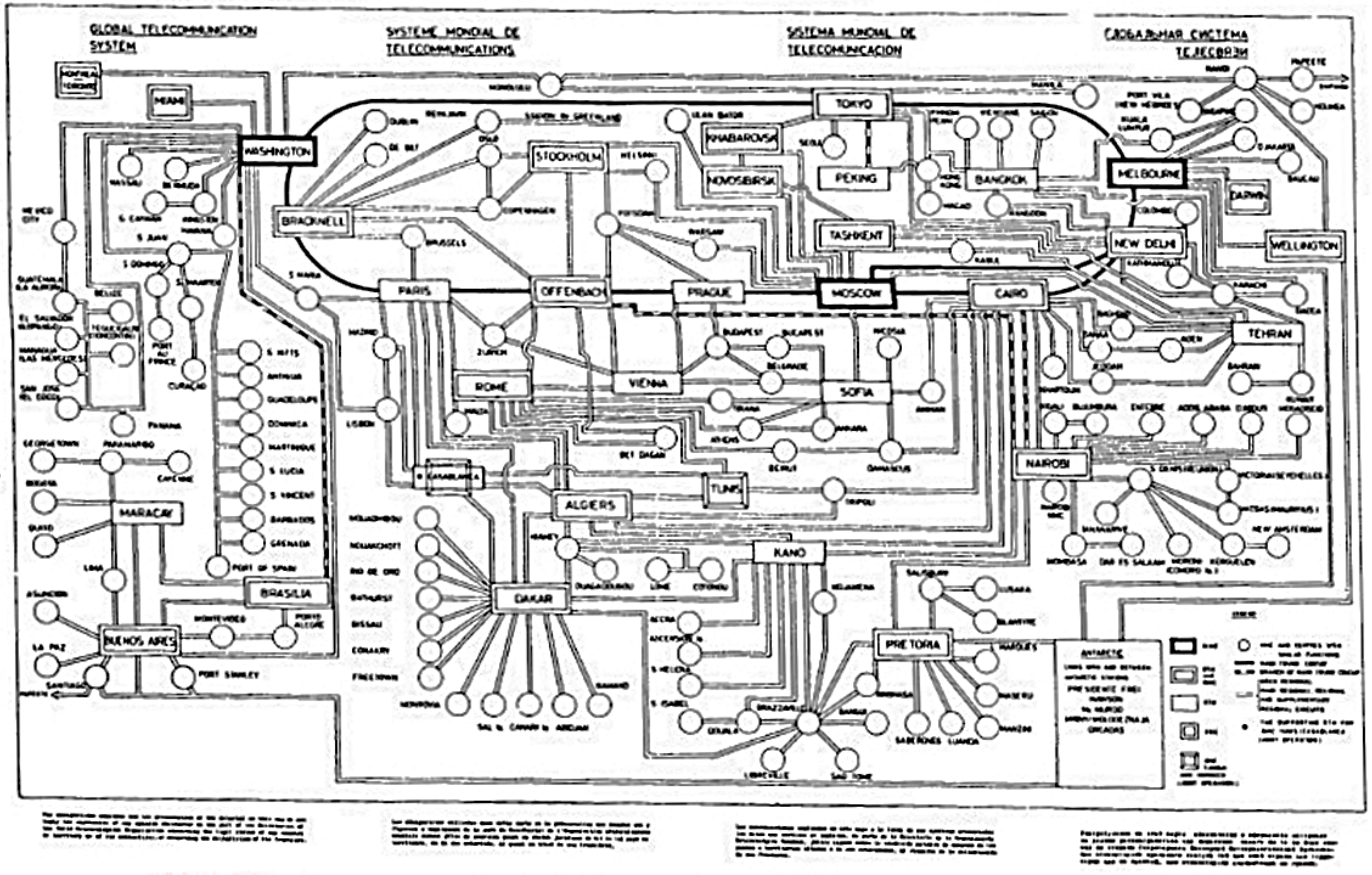



Figure 6.1 Schematic view of the WMO/GTS communications network.

# Initial GSE Level I Data Exchange

**GSETT-1 (Group of Scientific Experts Technical Test) Experiment (1984)**

**Initial concept of international data exchange adopted by the GSE**, based mainly on parametric (level I) data (seismic bulletins).

- Seismograms analyzed daily in each seismic station.
- Parameters visually extracted from seismograms by the analysts.
- Bulletins containing arrival times and amplitudes in standard format prepared in each National Data Center (NDC).
- Bulletins sent by **telex** over the **World Meteorological Organization (WMO) communication systems**, with the **concept that all the data are available to all participants**.

**Each phase reported in the bulletin should include**:

- Arrival time.
- Phase name (according to the IASPEI standard) if known.
- Amplitude and period of the ground motion.
- (For teleseismic P waves only) Maximum amplitude in the first 2-5 s.
- (For teleseismic P waves only) Maximum amplitude in the next 25-30 s.

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# The GSE at the End of Its First Mandate: March 1978


**Standing, from left to right:** V. Kàrnik, I. T. Noponen, J. Hjelme, E. Bisztricsàny, M. M. Schneider, A. J. Meerburg, H.-P. Harjes, P. M. McGregor, R. D. Adams, P. W. Basham, A. R. Ritsema, J. R. Filson, P. K. Iyengar, R. Hagengruber, B. M. Tygard, H. I. S. Thirlaway, L. S. Turnbull, R. Console, I. R. Kenyon, L. Ocola, E. S. Husebye, I. Passetchnik, I. Botcharov, O. Kedrov, H. Israelson, O. Dahlman, gentleman (not identified). **Seated, from left to right:** L. V. Hristoskov, S. Suyehiro, F. Ringdal, U. Ericsson, P. Csillag, lady (not identified), R. Teisseyre.

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# The GSE in the Early ‘80s

**Following the country alphabetic order:**

- P. M. McGregor, L. V. Hristoskov, P. W. Basham, V. Karnik, J. Hjelme, M. M. Schneider, H.-P. Harjes, E. Bisztricsany, P. K. Iyengar, R. Console, S. Suyehiro, A. R. Ritsema, R. D. Adams, L. S. Turnbull, I. R. Kenyon, 0. Kedrov, H. Israelson.



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# New Countries and New Experts Were Joining the GSE

**22 July 1986** official photo, among the others: R. Kebeasy (Egypt), X. Xian-jie (China), A.U. Kerr (USA), M. Henger (Germany, Fed. Rep.), S.J. Gibowicz (Poland), R. Alewine (USA), P. Johansson (Sweden), R.G. North (Canada), F. F. Pilotte (USA), D.L. Springer (USA), P.D. Marshall (UK), E. Johannisson (Sweden).

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# The GSE Workshops

- **The first: 1978, Japan, Tokyo,** included a visit at the Matsushiro Seismological Observatory.
- **Second one: 1980, Federal Republic of Germany,** Erlangen, included a visit at the BGR Grafenberg Array.
- **Several others followed**:



**Ottawa, Canada, October 1984.**

**Linkoping, Sweden, May 1988.**

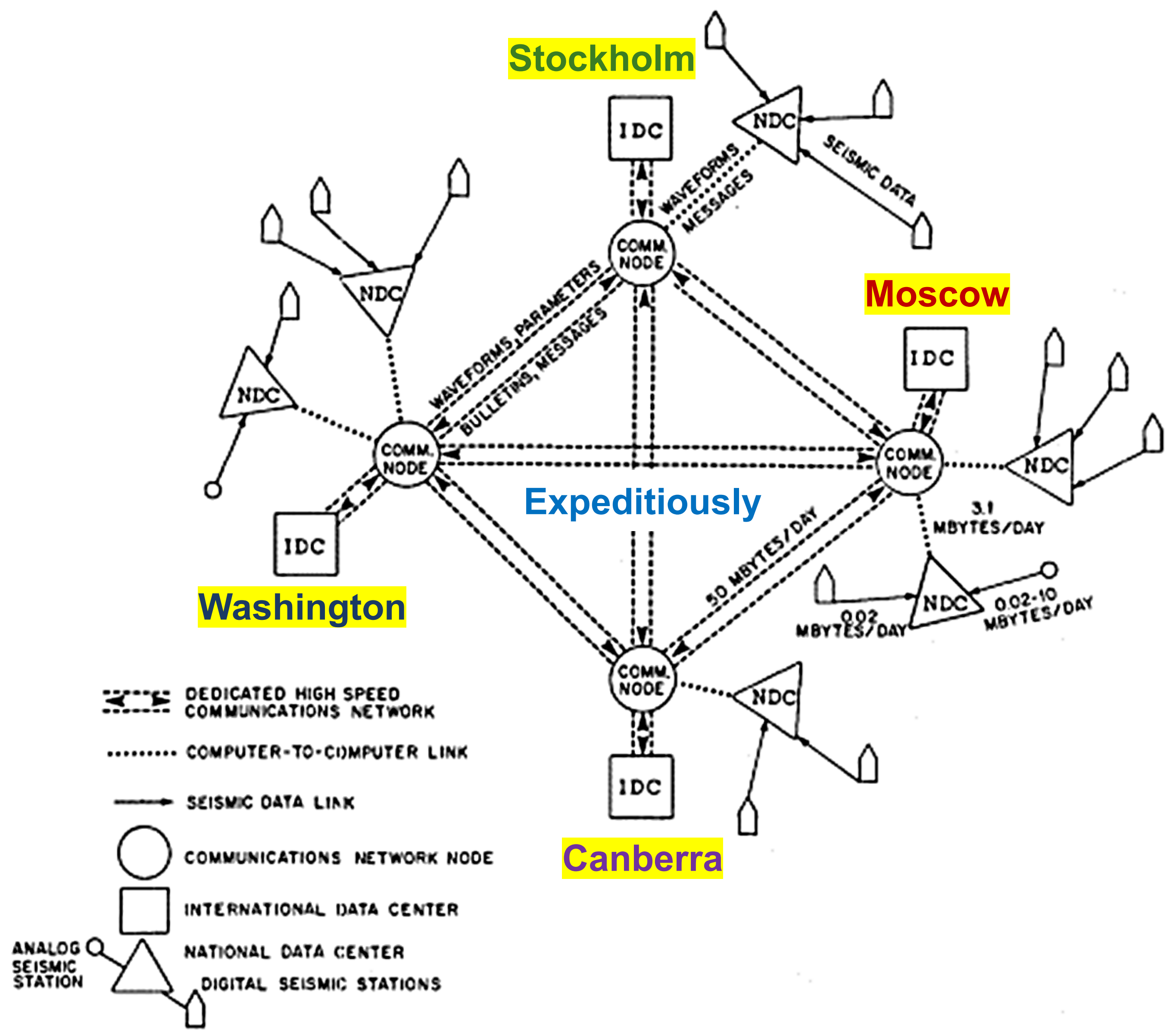
**Montebello, Canada, November 1992.**

# The Concept of Multiple IDCs

- GSE proposed in 1987 the concept of **multiple IDCs** in the **Global Communication System of the international exchange of seismic data**.

- It was tested during **GSETT-2, in 1991** (after an initial simpler form **in GSETT-1, in 1984**).

- From 80 baud (bits per second) by telex of the 1970's with bulletins only, to 3.1 MBytes per day of 1991 with exchange of waveforms via satellite link, to today's 36 GBytes/day.



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# CTBT *Ad Hoc* Committee – Geneva, 1993

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# GSETT-3 Workshop – Erice, Sicily – November 1993 (OSI concept – P. Marshall)

## ANNALI DI GEOFISICA

VOL. XXXVII, N. 3, June 1994

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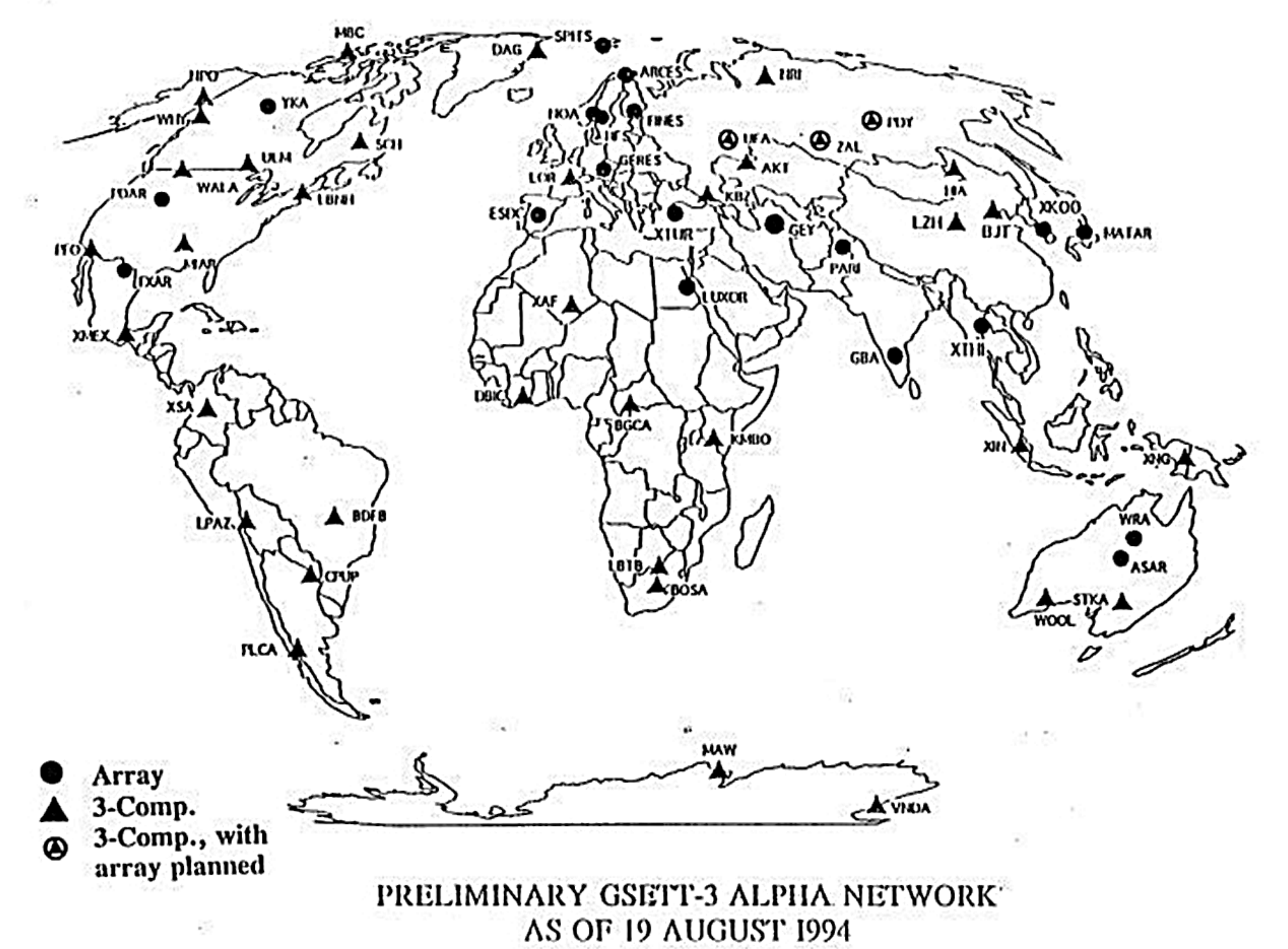
# Map of the GSETT-3 Alpha Network



# The GSETT-3 Prototype International Data Center (PIDC)

- The Prototype International Data Centre (PIDC) in Arlington, Virginia, USA, played a key role in the GSETT-3.

- The PIDC operated continuously between January 1995 and February 2000.

- Starting with seismic data only, the PIDC was responsible for real-time data collection, processing, analysis, and distribution of data and products.

- There was a smooth and orderly transition from GSETT-3 PIDC to CTBTO PrepCom's monitoring system (IMS and IDC).

**1995: Richard Gustafson demonstrating the PIDC capability**

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# GSE Final Meeting – Geneva, August 1996


**Standing, in the back row, from left to right, among others:** M. Tarvainen, E. Hjortenberg, O. Starovoit, P. W. Basham, J. R. Filson, M. D. Denny, R. Console, L. Toth, S. Mykkeltveit, M. Henger, H. Haak. **Standing, in the middle row, from left to right, among others:** J. Schulze, N.-O. Bergkvist, V. Kovalenko, B. Massinon, H.-P. Harjes, R. Alewine, H. Trodd, R. M. Kebeasy, M. De Becker, P. Johansson, S. Xu, R. Crusem, U. Kradolfer, W. Debski, I.-B. Kang, P. Harjadi. **Seated, from left to right, among others:** L. V. Hristoskov, S. Suyehiro, F. Ringdal, O. Dahlman, J. Mackby, N. N. Belyashova, C. Lopez.

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# The CTBTO International Monitoring System and the Vienna International Center


**Many GSE members continued activity as PTS staff or WGB delegates!**

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# *THANK YOU!*

*I am grateful for the support received from several GSE colleagues and other scientists in the preparation of this presentation.*

- Link to the **Nobel Laureate Assembly For the Prevention of Nuclear War** on occasion of the **$80^{th}$ Anniversary of the Trinity Test**, including the speech by CTBTO Executive Secretary Dr. Floyd, available here: https://vimeo.com/1099802892
- The full version of this presentation, containing also extensive bibliographic references, is available at: https://conferences.ctbto.org/event/30/contributions/6232/