Chapter 63 - **BRIEF HISTORY AND FUTURE PROSPECT**

Over the past seventy years, we have come from the discovery of the neutron to the present stage of neutron sources, neutron scattering and small-angle neutron scattering (SANS) programs. Great progress has been made in the use of neutrons as a probe for nanoscale structures in a wide variety of research areas. A brief history timeline of major events leading to the present state is presented. Then a few kind comments about future prospects are offered.

1. BRIEF HISTORY TIMELINE

-- 1932: Discovery of the neutron by Chadwick.
-- 1942: First controlled nuclear reaction by Fermi's team at the University of Chicago stadium (called Chicago Pile 1 or CP1). Other reactors were constructed at US National Labs (CP2 to CP5) over the following ten years.
-- 1945: Sadly, first detonation then use of a nuclear weapon.
-- 1953: Launch of the "Atoms for Peace" program by President Eisenhower.
-- 1955: Construction of the first university-based nuclear research reactor at Penn State University.
-- 1950s: First neutron scattering experiments at Oak Ridge National Lab.
-- 1960s: First power-producing nuclear reactors.
-- 1972: First SANS instrument built at the ILL (Grenoble, France) using a cold neutron source.
-- 1975: First spallation source demonstrated at the Argonne National Lab.
-- 1980-1982: First SANS instruments built at the Oak Ridge National Lab, the National Institute of Standards and Technology and the University of Missouri. These instruments used thermal neutrons.
-- 1985: First operating spallation source in the US at the Intense Pulsed Neutron Source at Argonne National Lab.
-- 1985: First horizontal cold source (inside a beam tube) in the US at the Brookhaven National Lab.
-- 1998: First cold source at a spallation source in the US at the IPNS.
-- 1990: First optimized cold neutron source (in the reflector region) in the US at NIST.
-- 1994: Nobel Prize to Brockhouse and Shull for their pioneering work on neutron scattering.
-- 2000's: Major upgrades in most neutron scattering facilities.

2. SANS USER STATISTICS

Following are some user statistics based on the number of SANS beamtime proposals submitted to the NCNR for each research category and for three proposal rounds.

Proposal Rounds	10	15	20
Year	2000	2003	2006
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Polymers	18	15	12
Complex Fluids, Chemistry	4	10	13
Biology	5	8	12
Materials Science	19	14	16
Condensed Matter Physics, Magnetism, Physics	14	8	4
Total number of beamtime proposals:	60	55	57

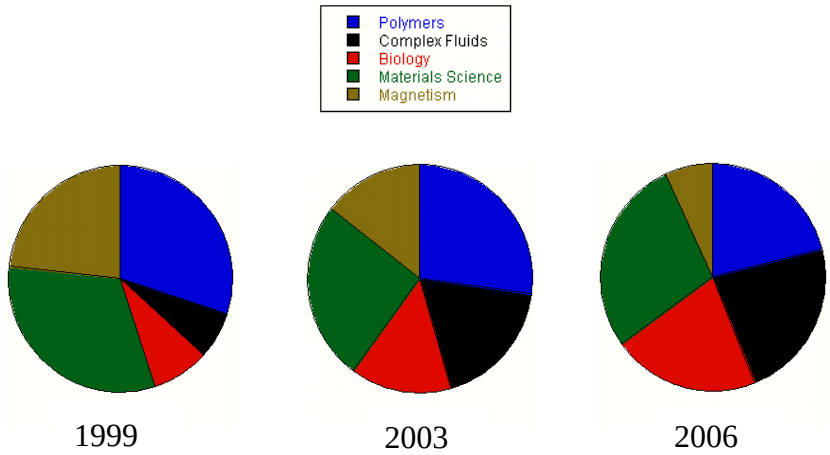

Figure 1: SANS user statistics at the NIST Center for Neutron Research for the years 1999, 2003 and 2006.

These are the total numbers of proposals that were allocated beamtime for three separate proposal rounds. Each proposal round covers a period of 7 months. This covers the full-time use of one 30 m SANS instrument and amounts to about 250 days per year. The numbers of submitted proposals were 2 to 3 times higher. Each accepted proposal gets usually between 2 and 3 days of beamtime.

3. SANS PUBLICATIONS

The NIST CNR has two 30 m SANS instruments in operation: one for the outside users program (through the proposal system) and one for the internal users program (through the beam time request system). During the past six years (2001 to 2007), a total of 522 papers were published resulting from the use of the NCNR SANS instruments. This is an average of 70 to 80 SANS publications per year. Moreover, over the same period of six years, about 70 PhD theses have been successfully defended by students that used the SANS technique. These are from various colleges mostly in the US. The SANS program is highly productive. A table summarizes the breakdown of SANS publications by research areas.

Year	2001	2003	2006
	---	---	---
Polymers	38	28	16
Complex Fluids, Chemistry	14	28	25
Biology	3	6	9
Materials Science	12	12	27
Condensed Matter Physics, Magnetism, Physics	2	2	4
Total number of SANS publications:	69	76	81

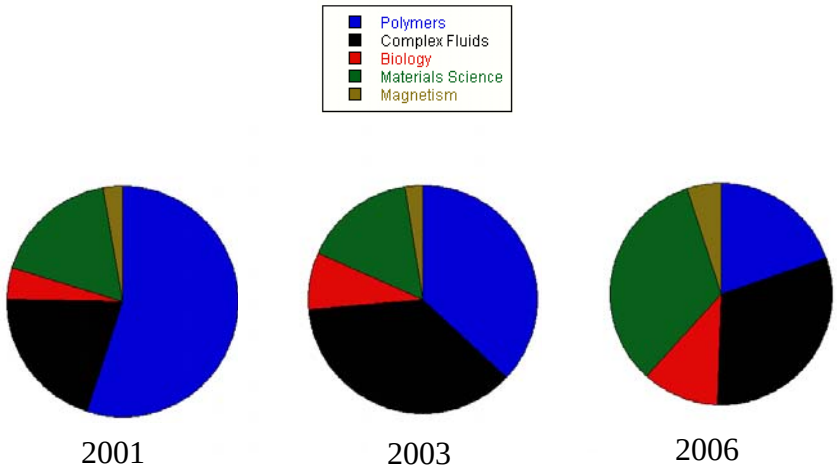

Figure 2: SANS publications resulting from the use of the NIST Center for Neutron Research for the years 2001, 2003 and 2006.

4. FUTURE PROSPECT

Future prospect for neutron scattering and its main SANS engine looks bright. In the US, the Spallation Neutron Source (Oak Ridge National Lab) went into operation, a horizontal cold source has been installed at HFIR along with a guide hall and two SANS instruments. The NIST Center for Neutron Research is undergoing a major expansion including a second guide hall. Major upgrades are planned at most neutron scattering facilities in the world. In Europe, the ILL's second guide hall has been fully equipped and the construction of the ISIS second (low-frequency) target is almost complete. In Asia, most neutron sources have undergone (or are undergoing) upgrades to acquire cold sources and guide halls.

SANS research has traditionally been strong in the areas of polymer science and complex fluids. These two research areas have constituted the lion-share of the user community. Use of SANS in biology has been increasing steadily moving from 5 % of the beamtime proposals to 25 % in just 15 years at the NIST Center for Neutron Research. Biology research may become the primary focus of SANS research. Recent advances in the

synthesis of peptide sequences and in the availability of deuterated amino acids are making a difference. Biologist are discovering the benefits of SANS.

5. THE NCNR EXPANSION

The NIST Center for Neutron Research is undergoing a major upgrade that includes the construction of a new guide hall. Both guide halls will be looking at the same optimized liquid hydrogen cold source. An assortment of new instruments will be constructed. These include a VSANS instrument that will cover the traditional SANS scattering range as well. Some instruments will be moved from the old guide hall to the new guide hall. Moreover, the design and optimization of a liquid deuterium cold source is under way.

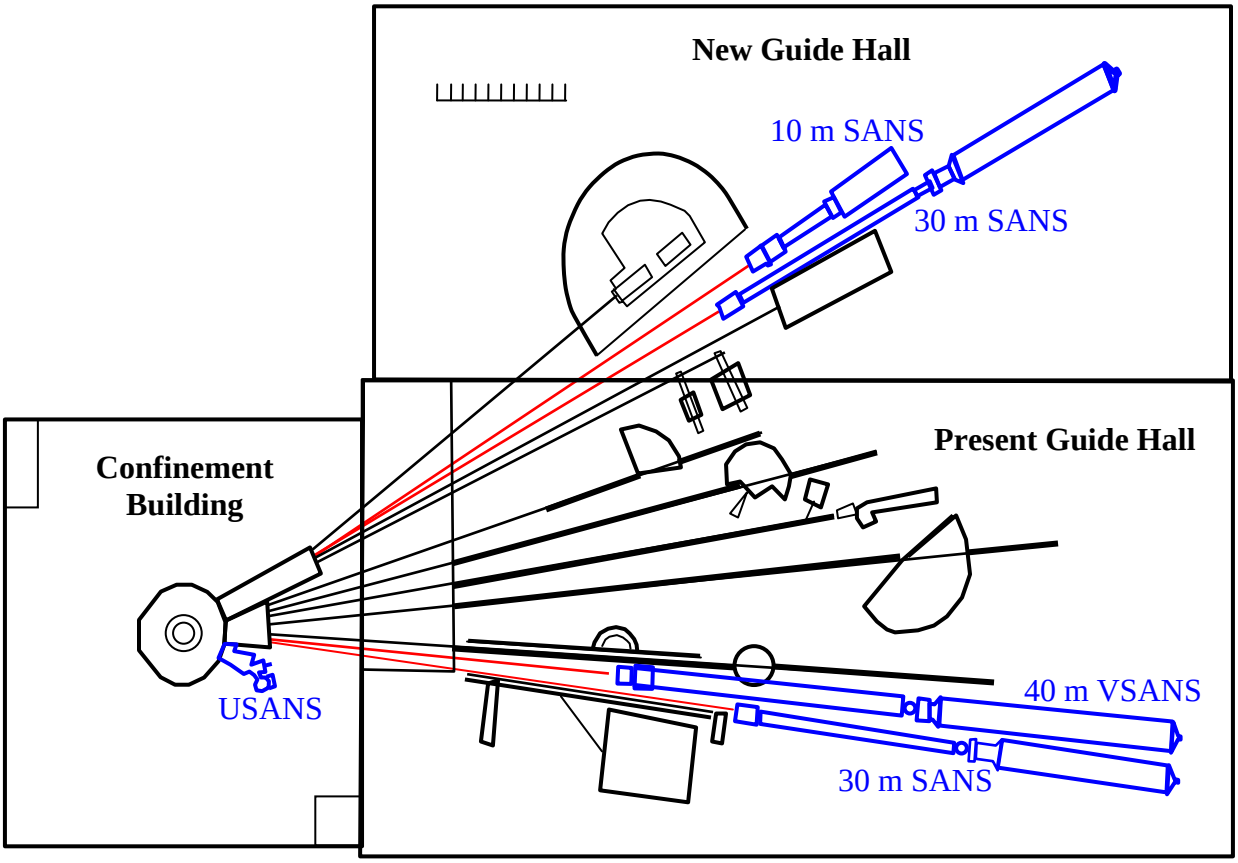

Figure 3: Schematics of the old and new guide halls at the NIST Center for Neutron Research. The old guide hall is almost 20 years old and the new guide hall is under construction. Ultimately, there will be two 30 m SANS instruments, a 10 m SANS instrument, a 40 m VSANS instrument and a thermal neutrons Bonse-Hart USANS instrument.

This expansion will keep nanoscale research alive and well, and growing for the next two decades.

6. FINAL WORDS

The SANS technique has gained maturity in many research areas. To quote my dear mentor Prof. Walter Stockmayer (one of the founders of polymer science) who once said: "Four great developments have made polymer science what it is today; these are the (1) advent of lasers and optical methods that followed, (2) Small-Angle Neutron Scattering, (3) the development of NMR, and (4) advances in computer speed for simulation purposes". The SANS technique has managed to grow steadily over the past twenty-five years from a "follow the trends" technique to a sophisticated characterization method used for studies in morphology, thermodynamics, and rheology. Advances in the use of judicious sample environments (shear cells, magnets, pressure cells, temperature quench apparatuses, etc) have instilled new momentum.

Other characterization methods are often brought to bare and complement the SANS technique. Some of these include Transmission Electron Microscopy (TEM), Wide-Angle X-Ray Scattering (WAXS), Ultra-Violet (UV) Absorption Spectroscopy, Dynamic light Scattering (DLS), Differential Scanning Calorimetry (DSC), densitometry, etc.

The SANS technique has been a driving force justifying upgrades of neutron sources and enhancements of neutron scattering facilities. Its use has been ever growing. It has managed to generate new momentum through novel technological advances as well as better modeling capabilities. The need for higher fluxes and better resolution has kept us all in business for a good many years. SANS will undoubtedly outlive many careers.

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