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From Fundamental Science to Fusion Energy – the First 50 Years of Fusion Theory

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With ITER, fusion energy research will reach the long anticipated goal of a stable, long-duration burning plasma – one that is largely sustained by fusion reactions. The history of progress towards this goal is intricately entwined with the development of the fundamental physics of plasmas and nonlinear systems. I will examine this history through three examples that highlight the role of theory and the Sherwood meeting. In the first example, I will discuss the development of stability theory. I will begin with the magnetohydrodynamic energy principle calculations of the 1950s and trace advances to the recent sophisticated kinetic calculations of ITER's stability to alpha particle driven modes. The development and application of chaos theory in fusion research will be my second example. I will trace its growth from field-line tracing for the first stellarators to the design of the ELM mitigation coils in ITER. In the final example I will examine the development of plasma turbulence theory to describe the transport of plasma heat and particles in fusion experiments. My (abbreviated) history of plasma turbulence will begin with Bohm's curious formula for turbulent transport and finish with the latest gyro-kinetic simulation of ITER like plasmas.