LIDS – A BRIEF HISTORY

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The Laboratory for Information and Decision Systems (LIDS) is MIT's oldest laboratory and has evolved in scope and changed its name several times during its long and rich history. For a more detailed account of its early years, see From Servo Loops to Fiber Nets*, a document produced in 1990 by then-co-directors Sanjoy K. Mitter and Robert G. Gallager as part LIDS' 50th anniversary celebration.*

The 1940s into the 1950s

The ***Servomechanism Laboratory*** was established in 1940 by Professor Gordon Brown, one year before the United States entered World War II. At that time, the concepts of feedback control and servomechanisms were being codified and recognized as important disciplines, and the need for advances – initially driven by military challenges and later by industrial automation – were substantial. Indeed, the first electrical engineering department courses in servomechanisms were created only in 1939 and were codified in the classic 1948 textbook *Principles of Servomechanisms* by Gordon Brown and Donald Campbell. Wartime applications such as servo controls for the pointing of guns pushed the application and the foundational methodology and theory of servomechanisms and control.

On the theoretical/methodological side, this push led to the 1957 text *Analytical Design of Linear Feedback Controls,* by George Newton, Leonard Gould, and James Kaiser, which combined Norbert Wiener's theory of estimation of time series and the principles of servomechanisms to create new approaches to control design and the understanding of fundamental limits of performance.

On the applications side, military and industrial post-war challenges led to major programs and contributions by researchers in the Lab. Among these was the celebrated **Whirlwind Project**, led by Professor Jay Forrester in the mid-1940s, initiated to provide the U.S. Navy with the capability to simulate aircraft dynamics. That project led to much broader and profound contributions to the development of digital computers, most notably through the development of random access magnetic core memory. The Whirlwind Project demonstrated the close connection among developments in computation, computers, and control, a connection at the

core of the Servomechanism's major contributions in numerically controlled machines in the 1940s and early 1950s, the APT system, and the beginnings of computer-aided design.

The 1950s

Gordon Brown directed the Servomechanism Laboratory from 1940 to 1952, followed by William Pease, 1952-1953, and Professor J. Francis Reintjes, 1953-1973. In 1959, the Lab's name was changed to the ***Electronic Systems Laboratory (ESL)***, reflecting the broadening of its research portfolio and the recognition that the fields of control, information, and computation were inextricably linked. This broadened agenda included the **Porcupine and Radar Projects** in the 1950s, as well as one of the first major programs in digital information storage and retrieval, **Project Intrex**. Significant events on the world stage, perhaps most notably the launch of Sputnik I in 1957 and the space race that followed, as well as the opportunities offered by the growing power of digital computation, provided the setting for a revolution in control theory.

The 1960s

Modern control theory, based on state variable models and encompassing the emerging field of optimal control, exploded on the scene in the 1960s. The core group of ESL faculty – Michael Athans, Roger Brockett, Leonard Gould, Timothy Johnson, Sanjoy Mitter, Ian Rhodes, Fred Schweppe, Jan Willems, and George Zames – played a major role and made groundbreaking contributions to this growing field. Path-setting texts written by ESL faculty during this time include *Optimal Control* by Michael Athans and Peter Falb, *Finite-Dimensional Linear Systems* by Roger Brockett, *Chemical Process Control: Theory and Applications* by Leonard Gould, and *The Analysis of Feedback Systems* by Jan Willems. Moreover, ESL served as the home for an impressive cadre of graduate students, many of whom went on to become important leaders in academia and industry.

The 1970s

The early 1970s saw the further evolution of the Lab's intellectual agenda. Researchers in LIDS recognized that the range of problems requiring the methods and perspectives of information, decision, and control was far broader than historically seen within the Laboratory. Michael Athans became director in 1974,

serving until 1981, and in 1978 the Lab once again changed its name, this time to the ***Laboratory for Information and Decision Systems (LIDS).*** As was the case with the previous name change, the change to LIDS recognized a broadening of the domains of research that had been under way for several years.

One of the major initiatives, led by Michael Athans, Nils Sandell, and Robert Tenney, involved distributed and interconnected systems in which measurements, decisions, and controls are not collected or performed at a centralized location, but are distributed. Issues of design, analysis, optimization, and control of such large-scale systems ushered in a new range of applications and the recognition that the disciplines of communications and networks were inextricably connected to this emerging research agenda. At this time, the LIDS faculty expanded to include many scientists involved in these disciplines, including Robert Gallager, Pierre Humblet, Robert Kennedy, Cyril Leung, Adrian Segall, Jeffrey Shapiro, and somewhat later by Mitchell Trott, and Vahid Tarokh. Their work was driven by the need for applications in communication networks, a research domain led by Dimitri Bertsekas and Robert Gallager; manufacturing systems, led by Stanley Gershwin; transportation systems, led by Paul Houpt; and military command, control, and communication systems, led by Michael Athans and Nils Sandell.

The 1980s and into the 1990s

Through the 1990s, substantial developments in control theory and practice permeated the international research community. Many of these advances originated with LIDS activities and research, including investigations that exposed the shortcomings of “modern” control methods and efforts to overcome them, which provided the first steps and foundation for the field of robust control. This work was spearheaded by Michael Athans, and MIT Adjunct Professor and Honeywell, Inc. senior engineer Gunter Stein, several students including Michael Safonov, and later by Munther Dahleh. The foundations of numerically sound methods for control system design also had their origins in LIDS in work led by Alan Laub, as did the development of methods for automatic failure detection in dynamic systems, led by Alan Willsky. Additionally, the blurring of the boundaries between computation and control led to significant advances in software-enabled control and methods for analysis and design of embedded control systems, led by Munther Dahleh, Eric

Feron, and Alexandre Megretski. The impact and influence of these efforts on basic research and practical and advanced system design are profound and continuing.

Estimation theory, i.e., the extraction of information about the state of dynamic systems from sensor measurements, also grew and evolved substantially under the leadership of Sanjoy Mitter and Alan Willsky. In the 1970s and 1980s, major theoretical advances were made in the theory of nonlinear filtering, with LIDS researchers at the center of many. Thanks to the encouragement of Alan Oppenheim, a LIDS colleague at the Research Laboratory for Electronics (RLE), Alan Willsky explored the relationships between control and signal processing in the late 1970s. His work led to a much broader look at the role of estimation in the context of extraction of information from complex signals and other sources of data. This exploration continues today, led by Willsky, Mitter, and Devavrat Shah, and includes research in statistical signal and image processing, computer vision, graphical models, and machine learning, fields that have contributed to the strengthening of cross-laboratory ties with RLE and the Computer Science and Artificial Intelligence Laboratory (CSAIL).

Particularly notable during the 1980s and 1990s was LIDS' role, under the leadership of Sanjoy Mitter (LIDS Director and Co-Director 1981-1999) in the Army Research Office-sponsored Center for Intelligent Control Systems (CICS) from 1986 to 2000. Not only did CICS provide much of the research funding during those years, but it also played a major role in renewing and strengthening LIDS' leadership role in the larger research community, including direct partnerships with Brown and Harvard universities.

LIDS from the 1990s to the present

The broadening of LIDS' research agenda in the mid-1970s was prescient and grew and evolved into major themes in networked systems and distributed algorithms. Beyond the tenure of Director Michael Athans, the Lab's scope continued to expand under the directorships of Sanjoy Mitter (1981-1986), Mitter and Robert Gallager (1986-1999), Vincent Chan (1999-2007), and Alan Willsky and Thomas Magnanti (2007-present). From these efforts have come major advances in data communication networks, led by Dimitri Bertsekas and Robert Gallager; parallel and

distributed algorithms, led by John Tsitsiklis and Dimitri Bertsekas; estimation and filtering theory, led by Sanjoy Mitter, Bernard Levy, and Alan Willsky; network coding, led by Muriel Medard; advances in coding and information theory, led by Robert Gallager, Lizhong Zheng, and David Forney; message-passing algorithms for large-scale inference and sensor and peer-to-peer networks, led by Devavrat Shah and Alan Willsky; ultra-wideband systems and location-aware networks, led by Moe Win; satellite and optical networks, led by Vincent Chan and Eytan Modiano; model reduction and multiple time-scale analysis of complex systems, led by Alexandre Megretski, Shankar Sastry, and Alan Willsky; computational robust control for both linear and nonlinear systems, led by Munther Dahleh, Eric Feron, and Alexandre Megretski; decentralized and distributed control and advanced aerospace information systems, led by Eric Feron, John Deyst, Emilio Frazzoli, and Jonathan How (including the major role played by How and Frazzoli in MIT's entry in the 2006-7 DARPA Urban Challenge); the interplay between control and information theory, led by Sanjoy Mitter and Munther Dahleh, towards an understanding of the limitations of control over noisy communication channels; natural language modeling and processing, led by Robert Berwick; and the currently emerging field of social networks, networked dynamic systems, and network games, led by Asuman Ozdaglar and Munther Dahleh, who collaborate closely with Daron Acemoglu in the Department of Economics, reinvigorating the ties between LIDS and economics first explored by Michael Athans in the 1970s.

One of the core areas of expertise within LIDS has been and remains optimization theory and methodology. The history and continuing impact of this work are substantial, originating with the research on optimal control and optimization algorithms of Michael Athans and Sanjoy Mitter, and continuing with the long history of advances by and leadership of Dimitri Bertsekas and John Tsitsiklis, the contributions in game theory and optimization of Asuman Ozdaglar, and the major advances and powerful new methods introduced and developed by Pablo Parrilo. Throughout the years, LIDS work in this field has bridged intellectual centers of activity within MIT, most notably through the close and continuing research and education ties between LIDS and the Operations Research Center (ORC).

LIDS roles in the broader academic and engineering community

Throughout its history, LIDS has grown and maintained strong partnerships within MIT, with industry, and with others across the international research community. Ties to RLE, CSAIL, and ORC remain strong. LIDS' 2004 move to its current home in MIT's Stata Center, located between RLE and CSAIL, strengthened those ties even more. Recently, LIDS faculty and staff have expanded their intellectual footprint across MIT, with growing ties to the department of economics, the MIT Energy Initiative, and the new MIT Environmental Research Council. Ties to other universities continue to strengthen LIDS as well – through joint research programs, LIDS' hosting of visitors, LIDS alumni joining faculties at other major institutions, and graduates of other prestigious universities and institutes joining LIDS.

LIDS interactions with industry include the generous contributions by and intellectual collaborations with the Charles Stark Draper Laboratory; the long and continuing history of joint programs and collaborations with MIT Lincoln Laboratory, BAE Systems Advanced Information Technologies (BAE-AIT), Honeywell, Inc., Ford Motor Company, Shell Oil Corporation, and Qualcomm; and growing collaborations with Microsoft Research and Siemens Corporation.

In addition, LIDS alumni and faculty have played major roles in founding and building successful companies including ALPHATECH, Inc. (now BAE-AIT), founded by LIDS faculty members Nils Sandell, Michael Athans, and Alan Willsky; Sycamore Networks, co-founded by LIDS alumnus Richard Barry; Flarion Technologies (now QUALCOMM Flarion Technologies), co-founded by LIDS alumnus Dr. Thomas Richardson; FastForward Networks (acquired by Inktomi) and Flowgram, Inc., founded by LIDS alumnus Abhay Parekh; OPNET, founded by LIDS alumni Alain Cohen and Steve Baraniuk; Atoga Systems (acquired by Arris International), Berkeley Networks (acquired by Fore Systems), and LeapTag, founded by LIDS alumnus Cuneyt Ozveren; Jackson Hewitt Tax Service (acquired by Cendant), Chainwave Systems, Inc., and Immedia Semiconductor, led by LIDS alumnus Dr. Dan Grunberg; Aris Capital Management, founded by LIDS alumnus Jason Papastavrou; and Enuvis, Inc. (acquired by SiRF Technology), co-founded by LIDS alumnus Ben Van Roy and LIDS faculty member John Tsitsiklis.

LIDS faculty have also played major roles in education, through teaching, the development of courses in home departments (primarily the Department of Electrical

Engineering and Computer Science and the Department of Aeronautics and Astronautics), and the publication of numerous research and basic textbooks. Publications include texts by Dimitri Bertsekas and John Tsitsiklis on probability, networks, optimization, and stochastic control, which have largely shaped the curriculum in these areas at MIT and beyond; Munther Dahleh and Ignacio Diaz-Bobillo on computational robust control; and Alan Oppenheim and Alan Willsky's *Signals and Systems*, the most widely used basic text on the subject over the past 25 years.

LIDS faculty and alumni have an exceptional record of awards and recognition, beginning in the early years of the Lab and continuing to the present. Awards include recognition for research contributions and papers, honorary degrees, membership in national academies, and roles in major national and international scientific advisory boards and committees.

Looking toward the future

Today, LIDS continues its cutting-edge research and application in the science of information and decision systems, educating and training new generations of research and engineering leaders and evolving as new challenges and innovations emerge. Its faculty, staff, and students continue to advance and lead, and the Lab stands as a singular institution, not only within MIT but in academia and industry throughout the world. Indeed, those who have called LIDS home since 1940 – students, research staff, faculty, and visitors – are an extraordinarily bright and accomplished community, and LIDS continues to attract the best and provide an environment in which great things happen. Our history is rich and deep, but it is only a beginning.