What is Systems Design Engineering?
Alex Pak, Class of '01, takes an introspective journey into the origins and underlying vision of our program.

Origins of SyDe, *Abridged…*

By: Alexander Pak, Class of 2001
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I. The "SD" Files

The question at the head of this article is one that is faced by all graduates of the Systems Design Engineering (SDE) program. Indeed, every undergraduate is asked the question during co-op work term interviews, full-time graduate position interviews, grad school interviews. Even before entering the program, the parents of every prospective SyDe student ask them this same question. After graduation, we get asked that question all the time.

And for some reason, after our four-and-two-thirds years in this intensive program, none of us has a good sound-bite to offer as an answer to the question. Why is that?

The truth is out there — or is it?

Perhaps it is a conspiracy of the highest order, a blanket mind-control effort by dark-suited powers that hide themselves from daylight and social scrutiny.

The truth is out there—or is it?

The faculty of the SyDe department freely admit that they have no satisfactory response when prospective and current students confront them with this question. There is no perfect answer, nor an official line, that satisfies everyone's curiosity. Professor Ed Jernigan, current Chairperson of the SyDe department, acknowledges the absence of an adequate "sound-bite" to offer students. Other departments have it easy: Mechanical Engineering can point to a car and say, "that is MechE"; Electrical Engineering can display a computer and say, "this is ElecE"; Civil engineering can point to a bridge or a skyscraper and say, "that is CivE". Systems Design is not so simply manifest in one thing: there is no simple archetype of the product of SyDe.

The existing SDE program is the result of an incremental, serendipitous, perhaps haphazard series of evolutionary changes.

"What is life?"

"You may as well ask, 'What is life'," says Prof. Jernigan, "and for the first few years in the SyDe undergraduate program, Systems Design *is* the student's life. There is no easy answer to 'What is Systems Design Engineering'… well, there is, but people aren't satisfied by it." Jernigan notes with amusement that there is an illusion in other departments that they know what their departments are (e.g. MechE, ElecE, CivE), but in fact there is still a broad spectrum of disciplines, interests, and research areas in any engineering discipline. Electrical Engineering, for example, can range from power

generation topics to embedded control systems development, to VLSI circuit design.

Yet, students and faculty of other departments—and the lay population at large—feel intuitively that they *know* what Electrical Engineering is, what Mechanical Engineering is, and what Civil Engineering is. Still, no one seems to know what Systems Design Engineering is. The question draws a collective social mental blank. Perhaps this is a result of media descriptions, or job openings, or firms built on the principles of these "well-defined" disciplines. Or perhaps this is due to a perception of the clarity of the career path which a discipline like Mechanical or Electrical affords.

Or perhaps it is a conspiracy of the highest order, stemming from the Department of Systems Design Engineering itself.

What Systems Design Engineering lacks is a clear social comprehension of how SyDe contributes concretely to the ongoing Tower of Babel that is human achievement. This article represents my personal attempts to chase down a clear, concise description of what Systems Design Engineering *really* is, one that will satisfy myself and the parents of SyDe graduates everywhere.

In Rashoman fashion, there are several perspectives from which we can build an understanding of what Systems Design Engineering is: outside-in, top-down, bottom-up, and inside-out.

II. Outside-in: The Very Unsystematic Design of a New Program

In the beginning there was darkness. And from the darkness, Soulis said, "Let there be light," and there was light. And the light was good, and Soulis said, "Let this light be Systems Design Engineering." And it was so. And the morning and the evening were the first day of classes.

This is *not* how Systems Design came into being. Professor Peter Roe, one of the original minds at the helm of SYDE, is very adamant to describe that the existing SYDE program is the result of an incremental, serendipitous, perhaps haphazard series of evolutionary changes.

Two Travellers: George Soulis and Peter Roe

In 1960, George Soulis came to UW as an extremely prolific mechanical engineer; at the time, he had registered over 50 patents. In a meeting with the founding Dean of UW Engineering, he noted that throughout his entire engineering education and career as a practicing engineer, he never learned a thing about engineering design; he had picked up design methods and principles entirely on his own. He had an idea for a way to teach engineering design in the existing engineering curriculum, and was then sent to Bonn, Germany to study at the High School for Design (one of the two offshoots of the original disbanded Bauhaus design group).

At around the same time, Peter Roe was studying for his Ph.D. under H. K. Kesavan. Nominally, Roe's dissertation was in Electrical Engineering. In fact, his research was in Systems Analysis, specifically Systems Modelling and Graph Theoretic applications of Systems Models. However, Roe had a hankering interest in Engineering Design, and was sent by Dr. Kesavan to Dartmouth University in New Hampshire, to participate in an experiment involving how to teach design. The experiment consisted of 5 faculty and 60 student participants: each faculty member coached a group of twelve students on a uniform design project—how to make brackish water drinkable. The five groups were loosely competitive and prizes were awarded to the best designs. The faculty then wrote up their notes on the design process and the process of teaching the principles of design.

Professor George Soulis (Mechanical Engineering) then created the Institute of Design at UW, along with Professor Roe (Electrical Engineering) and Professor Johann (Civil Engineering)… Very quickly, the Institute landed a watershed contract with Expo '67 in Montreal, to design 3 of the 6 pavilions.

Out of sheer necessity, a rogue's gallery of specialists were hired to fill the faculty positions of the newly expanded department: film makers, architects, civil engineers, mechanical engineers, electrical engineers, and human factors specialists fleshed out the department faculty roster.

Roe returned to Canada in 1963. At nearly the same time, George Soulis returned from Germany.

Soulis had managed to convince the Dean of Engineering to let them teach a mandatory, faculty-wide, first-year engineering course in design. The course was labelled General Engineering (GE) 11. Along with Professor Handa, George Soulis and Peter Roe sat down to write a course book. This book was used in the fall of 1964 when the trio led seven hundred engineering students—3 sections of 230 students each—through lectures on design. At that time, the only space on campus that could hold that number of students was the Theatre of the Arts.

At this time (1964), graduate students in engineering were plentiful and government funding was abundant. Eventually, an army of grad students were taught how to teach and manage the design workshops. The course would end in competitions, or "design showdowns" as Roe remembers them, with prizes given to the top project in each lecture group—handsome beer steins engraved with the UW Engineering Logo.[1]

This first-year design class, GE 11, was the prototype of the current 1st year design course, Systems Design (SYDE) 161.

The Newly-minted Department of Design: A Rogue's Gallery

Professor George Soulis (Mechanical Engineering) then created the Institute of Design at UW, along with Professor Roe (Electrical Engineering) and Professor Johann (Civil Engineering). A textbook for the design course, GE 11, was published. The Institute would do industrial design and engineering work under contract. Very quickly, the Institute landed a watershed contract with Expo '67 in Montreal, to design 3 of the 6 pavilions. The contract was immensely lucrative (equivalent to $20 million today), and the funds allowed the fledgling Institute of Design team to hire people as associate and assistant professors and to help on the huge design projects. A new Department was started at UW: the Department of Design.

After a legendary Faculty Council meeting in 1965, a vocal floor fight saw the Department of Design approved by a margin of one vote. Two design programs were instituted: a Masters degree program and a diploma program. In addition, the newly-minted Department of Design would assume all of the teaching duties for the undergraduate design and graphics courses. With 750 engineering students, and 600 other students, the fractional funds from tuition alone could justify the department *financially*. However, it quickly became clear that you couldn't run a department *sociologically* with just a Masters program. Soulis approached the Faculty council again and was granted the power to add a Ph.D. program and an undergraduate program at the same time.

At that time, it was not necessary for a prospective professor to have a Ph.D. to secure a faculty position. Out of sheer necessity, a rogue's gallery of designing specialists were hired to fill the faculty positions of the newly expanded department: film makers, architects, civil engineers, mechanical engineers, electrical engineers, and human factors specialists filled up the department faculty roster. Professor Calamai, current Chairperson of Graduate Studies in the SyDe department, fondly notes that Kish Hahn, a well-loved faculty member and champion of Human Factors, was a professional photographer when he was originally offered a place in the Department of Design faculty.

With the tremendous diversity of creative talent, the pressing issue became how to use the people they had. It was proposed that the Department of Design be divided into an Architecture program, to be headed by Soulis (at that time, Architecture was part of the Faculty of Engineering); a Ph.D. program, to be headed by Roe; and a Faculty of Professional Studies (FPS), which was to house a five-year undergraduate program: a three-year pre-professional degree followed by a two-year specialist degree in either Architecture or Engineering.

The Transition from "Design" to "Systems Design Engineering"

Struggles lay ahead as the entire Faculty of Engineering was uprooted in transformation as it struggled to redefine itself in 1968. A new Faculty of Environmental Studies was initiated at UW, which comprised Planning, Geography, and Architecture studies under its aegis. The Department of Design therefore lost its bid for the Faculty of Professional Studies undergraduate program. But under the first Chairperson of the Department of Design, Professor Kesavan, the Department would obtain permission to create their own undergraduate engineering program. In the fall of 1968, the Department of Design became the Department of Systems Design Engineering, and the superfluous faculty became part of the newly-created Department of Management Sciences.

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The proposed undergraduate program in Systems Design Engineering would consist of a three-year general program, one

[1] Later, students would be divided into cohorts of 120 students supervised by a "super TA", and into five groups of 24 students, each led by a regular teaching assistant. Each TA then divided their 24 students into 4 project teams of 6 members.

year of specialization, and one more year of "deep study". Students were allowed to (forced to?) take more courses back then—up to eight per term!—and would start their electives earlier. The general program was designed to enable any SDE student to take any of the existing specializations (e.g. Civil, Mechanical, Electrical) or a few specializations unique to the SyDe department (e.g. Transportation Engineering). The Department of SyDe also took on Masters and Doctoral programs, while dropping the diploma program.

Various specializations existed at the beginning. Socio-economic systems (environmental), graph theoretic systems, computation (now "Intelligent systems"), and Human systems. Why these particular specializations? Well, these were the interests of the original faculty members, the rogue's gallery that comprised the department!

III. Top-Down: The Influence of the Department Chairs

Clearly, the ongoing evolution of the SyDe program since its inception owes its course to not only the program founders, but also the succession of Chairpersons of the Department. George Soulis, the Chair of the SyDe-prototype Department of Design, was a Mechanical Engineer obsessed with how to teach design. H. K. Kesavan, the first official Chair of the Department of Systems Design, was one of the first PhD students of H. E. Koenig who was part of a group in Illinois who wanted to expand electrical network theory using a graph theoretic approach to modelling systems. Kesavan was keen on expanding the field of how systems theory could be taught. Peter Roe was Kesavan's sole Ph.D. student at the time. The marriage of systems theory and design principles forged the Systems Design approach—and moniker—of the Department.

T. Fraser, who succeeded Prof. Kesavan as Department Chair, was an M.D. who introduced the human systems aspect to the department. Professor Barry Wills notes that Professor Fraser left his stamp on the department through his interest and emphasis on the human-technology interface. Wills also notes that the next Department Chair, Koncay Huseyin, was originally a Civil Engineer who fell in love with Systems Design Engineering: "He saw opportunities, lots of them, to do new things with Engineering" using the Systems Design approach. Huseyin added another aspect to SyDe through his interest in chaos theory and non-linear dynamical systems. Prof. Jernigan adds that the current blueprint of the SyDe undergraduate program crystallized under Huseyin's tenure as Department Chair: "He abolished the early design courses, to streamline the program down from 7 or 8 courses per term to the [now familiar] 5 courses per term. This was to allow time for students to get involved in extra-curricular activities." Jernigan hints that Huseyin understood the importance of cultivating capable *people,* not just capable engineers.

Wills rounds out the Chairperson roster by noting that Chandrashekar, Huseyin's successor, was a passionate individual who embraced environmental issues and energy topics. "Shakur," as he was affectionately known by both his students and colleagues, also left his mark by emphasizing the importance of teamwork and leadership. His sudden passage in 1997 left a void in leadership which was capably filled by Keith Hipel, who specialized in conflict analysis, political perspectives, and stakeholder analyses.[2] Perhaps it is a happy coincidence that Hipel stepped into leadership at roughly the same time the Ontario Government announced that they would implement massive reductions in university funding, and that tuitions fees could now float freely upward.

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Professor Ed Jernigan, current Chairperson of the Department, specializes in signal processing and intelligent systems, but also keeps his eye focused on the SyDe program as a system in itself. He currently champions the Shad Valley program at UW, which introduces high-calibre high school students to the university environment. The Shad Valley program also acts as a high-profile marketing channel to sell UW, and the SyDe program in particular, to the well-targeted and captive students of the Shad Valley program. Jernigan is also actively endorsing alumni efforts such as

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[2] It is generally recognized that there are three systems approaches to problem solving: "hard systems," or technological approach (what devices and systems will solve the problem), "soft systems," or sociological/methodological approaches (what people, organizations, or methods will solve the problem), and "political" approaches or stakeholder analyses (who stands to gain or lose when new technology or methods are introduced).

the development of a SyDe Alumni network.

The current challenges faced by Jernigan and the SyDe Faculty are the disappearing provincial and federal funding for universities, and the question of whether or not to address the funding challenges through the expansion of the SyDe program into two streams. Some members of the faculty believe that "small is beautiful," and that the small size of the SyDe Undergraduate program keeps it elite, while others believe that the program can scale into an equally successful larger program. The overriding issue is, predictably, funding: specifically, who will pay for the new facilities and the new faculty positions. Perhaps the current constraints on funding will result in an innovative and creative solution worthy of the maverick origins of the Department of Systems Design Engineering.

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IV. Bottom-up: If You Build It, They Will Come

The official mission of the Systems Design Department can be found on the Department Website.[3] It's unofficial mission is, "to produce the leaders of technology": that is, heads of firms, vice presidents, general managers. In the words of Peter Roe, the archetypal SyDe graduate is "a Jack of all trades, and master of *one."*

Professor Ed Jernigan, and current undergraduate Chairperson Dan Stashuk, note one major success and quality factor of the undergraduate SDE program: the students themselves. Stashuk notes that "clearly, a large part of the excellence of the program is the level of excellence of the students who are attracted to SyDe."

Jernigan concurs and adds that at the inception of the program the likely makeup of the student body was unknown. However, it very quickly showed a tendency to attract the *risk-takers,* the type of student who find the ambiguity of the program appealing: "the 'I don't know what this is, but I think it would be great' type of student… as we churned out grads who could think in systems terms, and could practice systems thinking and design methodology, then people came to appreciate that [the SyDe program] could be great."

But it wasn't always the case that the SyDe program drew the best and the brightest high school students in competition for the limited number of places in the first-year class.

Attracting the Best and the Brightest

In 1969, the first entering SyDe class had 60 students. The admission average was a shocking 63 percent. Roe stresses that Systems Design Engineering was a completely new concept, a new department, a wholly new field of engineering. In fact, it was so new that the faculty members actually phoned potential applicants to let them know that the program existed. At that time, no one from universities contacted applicants in any way, let alone cold-called them. Roe recalls that "the Dean of Engineering was up in arms. 'You can't do that!' was the general consensus. It was unheard of, for professors to call students. The other universities, and UW too, were all shocked and appalled."

But the tactic worked: "…prospective students were subtly asked if they had any questions about Systems Design Engineering, which of course inevitably led to the question, 'What is Systems Design Engineering?' and opened the door for a lengthy conversation."[4]

Students had a privileged opportunity to directly question a faculty member about the courses, options, specializations, how the program differed from the

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[3] http://www.systems.uwaterloo.ca/AboutUs/aboutus_mission.htm

[4] Author's note: In 1996, Professor Paul Calamai—acting Admissions Officer for SDE—contacted me at the behest of Professor Ed Jernigan—acting Dean of Admissions for UW Engineering—and asked me exactly the same question. I had not indicated SDE as one of my choices of program at UW, but by the end of the hour-long conversation I was convinced—and thankfully so—that SDE was the *only* program appropriate for me.

traditional types of engineering, and whether it would limit their choice of career or graduate study options. Parents were duly impressed that their sons and daughters were personally contacted by professors, perhaps providing the major influence on their child's decision of post-secondary study. Roe muses, "It was so successful, that the rest of the engineering divisions, UW, and [the universities of] the province started contacting applicants as a standard *modus operandi."*

The tactic, Roe suggests, was successful in attracting unique applicants because it was *innovative,* and "not in the same old mould as the other engineering [divisions]." The program attracted the indecisive, and gave students an opportunity to *wait* before making up their minds about a specialization. Perhaps accidentally, the SDE program consequently succeeded in attracting the broadest thinkers from among the most academically successful students. Perhaps the program appealed to the students senses of "the bigger picture": students could learn the fundamentals of engineering and get a taster's choice of a variety of specialities and disciplines in engineering.

The Systems Design Engineering program eventually succeeded in achieving the highest entrance standards (graduating high-school average marks) of all the UW Engineering divisions. "The only possible comparison in terms of entrance competition, and quality and rigor of the program itself, were Engineering Science at University of Toronto, and possibly Engineering Physics at Queen's University," says Roe, proudly. "But we were better."

One Man's Journey through SyDe

The SyDe experience can be experienced through the journey of one individual who has been associated with the department since 1972: Professor Paul Calamai, current Chairperson of Graduate Studies in the SyDe Department. The details below are what he "believes to be true," to the best of his memory.

Calamai's father was an aeronautical engineer. During his senior year in high school, Calamai found himself uncertain about his university path and, at the suggestion of his guidance counsellor, took a skills test—a multiple choice test which many high school seniors are familiar with. The results indicated something to the effect that he would be well-suited to become either a farmer or a priest. These puzzling results appeared to contradict his aptitudes in mathematics and science. In a later discussion with his guidance counsellor, he was told that she had just received a pamphlet from UW about a brand-new program called Systems Design Engineering. "From my strengths and uncertainties, the program seemed to be a good match," says Calamai. He was attracted to the program's versatility and the fact that he could defer his specialization. He applied to—and received offers from—the top engineering programs of his day: SyDe at UW, Engineering Science at University of Toronto, and Engineering Physics at McMaster University.

Calamai decided to attend UW in the fall of 1972. "The decision didn't have a lot to do with co-op or money, the main draw was that I didn't have to make up my mind." He originally found the socio-economic (management science) and human systems options appealing. Although he had no particular career in mind, engineering distinctly appealed to his aptitudes and sensibilities, likely due to his father's influence.

During his undergraduate years, Calamai was required to take design workshop components *every term,* and he also chose to take many elective courses, totalling up to 8 or 9 courses each term! He notes that there was a bit less variety in the course offerings back then, but he was particularly interested in the human factors courses. However, there turned out to be very few jobs and career opportunities in the field. Calamai recalls one co-op interview period when there was only one human factors job posting (an artificial pancreas project at Toronto General Hospital). He applied, and did not get the co-op job offer.

Calamai decided shortly afterward that there wasn't much of a career path in human factors at that time, and switched to taking electives in physical systems. Calamai fondly remembers the impact Professor Huseyin had on him in this respect, "his teaching style was inspired, and sparked an interest in me." Still, while Calamai enjoyed the material, it felt "less personal than—or the direct opposite of—human systems." Thus, Calamai made a third change in study to socio-economic systems. At the same time, other faculty members encouraged

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Calamai to consider an academic career. He did his 4A-4B design workshop with Professor Charalambous, at which point he decided that he wanted to be an academic. At this point, "it was just a question of where."

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Calamai was a member of the fourth graduating SyDe class from UW and he followed through with his Masters and Ph.D. in SyDe. He became a professor with the Systems Design Engineering Department immediately afterward. With the exception of a one-year break in 1984-1985, Paul Calamai has continuously been a member of the SyDe department: an undergraduate, graduate, doctoral student, and finally as a member of the SyDe faculty. He remains active in the Department today.

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V. Inside-out: Turn and Face the Strange Changes

It is especially true of Systems Design Engineering that every stream of learning is a product of its time. Jernigan proudly stresses that while the interests of industry and students change from time to time—plastics and chemical engineering in the 1960s; electrical engineering in the 1970s and 1980s; computing and intelligent systems in the 1990s; mechatronics, biotechnology and nanotechnology in the 2000s—the attraction of Systems Design Engineering remains steady: "the nice thing about [Systems Design Engineering] is that SyDe can accommodate the ebb and flow of those interests… therefore, SyDe is not prone to the fear of being left high and dry by the whims of fashion."

While the interests of students, reflected in the design projects of the third- and fourth-year SyDe undergraduates, generally present a portrait of the department through the Design Colloquium publication, the interests of the faculty equally influence the flavours of the department at any given time. "Classes and course offerings change with respect to faculty interests," notes Calamai. For example, in the not-so-distant past, Human Systems seemed to be going through a "sunset" period in the department: the faculty were aging and nearing the end of their academic careers, and no new graduate students were taken on to pursue human factors projects. The "old guard" of the human systems faculty can be seen in the likes of Kish Hahn, who specialized in physical human dynamics, anthropometry and biometrics.[5] However, a "new wave" of human systems and human factors faculty have rejuvenated this specialty of the SyDe department. Dan Stashuk specializes in EMI and body-generated signals; Catherine Burns focuses on human-computer interaction; Carolyn MacGregor is an expert on cognitive engineering and ergonomics, or "neck-up" human factors engineering. Similar rejuvenations in other specialties of the department occur from time to time—from computing to intelligent systems and machine vision; from control systems to neural networks, fuzzy logic, and mechatronics. These transitions infuse new life and spirit into the department.

The word universally invoked by the professors interviewed for this article is *"evolution":* evolution of the department structure, of faculty makeup and interests, of student and industry inclinations. Yet, the more things change, the fundamentals strongly remain the same. Professor Ed Jernigan reinforces that the current mission of the department is still "to create the leaders of tomorrow… to make engineers who are broad thinkers, not narrow thinkers… the sort of person ideally suited for leadership roles."

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Jernigan stresses the need for technical fluency among SyDe

[5] This "hard" element of human systems and human measurement is now the domain of the Department of Kinesiology.

graduates: "we want the leaders to be technically conversant." In fact, Jernigan wants more than technical fluency: he wants practicing engineers. Perhaps the department does do a good job of developing leadership and management ability in its graduating classes, because a significant fraction of the SyDe graduating classes are attracted to the Management Science option and consequent careers in management consulting. Jernigan finds this frustrating: he would rather see a larger portion of the class aspire to become high-calibre practicing engineers, as opposed to jumping into project management and consulting roles. "Moving from engineering positions to leadership positions is okay, but you need the technical knocks to really be effective leaders."

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VI. Conclusion

Clearly, there is no straight and simple verbal answer to the question, "What is Systems Design Engineering?" In fact, all of the professors interviewed for this article concur that "there is no *one thing* that 'Systems Design' is," as Professor Calamai notes. "Everyone in the 'Professors Corridor' [a hallway in the Davis Centre that holds all the SyDe professors' offices] is passionate about the department but would disagree about what exactly [the Department of Systems Design Engineering] is."

The department is greater than a slick sound-bite can contain. Professor Jernigan observes that it was not the mission of the department that attracted him, but the *environment* of the department. Professor Stashuk warmly notes that one of the positive externalities of being an SDE faculty member is walking down Professor's Corridor with his research ideas and getting a dozen unique insights and points of view from his faculty peers in the department.

Professor Wills notes that, since the beginning, the department has attracted a wide variety of faculty research interests to explore many different kinds of problems and expand the sense of what Systems Design Engineering is and can be. In fact, it is a lynchpin of the faculty hiring process to ask each candidate what they think Systems Design could be. The candidate's response to the question acts as a mirror, reflecting what the candidate feels they can bring to the SyDe department.

Even the graduates and the faculty alumni of SyDe leave a diasporic miasma of opinions in their wake about what SyDe is. Canadian universities are attempting to jumpstart their own SyDe-modelled departments, with varying degrees of success. For example, one enterprising university has renamed their computer engineering division to the "Systems and Computer Engineering" department. Clearly, this falls short of the essence of Systems Design Engineering.

There is one thing that is certainly maintained about the SyDe program: the hearty reception of its excellence by industry and by other universities. Sujeet Chaudhuri, the current Dean of Engineering, is proud to point out that "all our responses from industry about the Systems Design Engineering program have been overwhelmingly positive." Perhaps, in the final analysis, there are only a few things that need to be remembered in response to the questions, "What is Systems Design Engineering?"

1. It is a top-tier program that creates the leaders of technology and the leaders of tomorrow.
2. It attracts, supports, and graduates broad thinkers, not narrow thinkers.
3. It espouses a systems approach to problem solving.
4. It uses a methodological approach to problem analysis and engineering design.
5. It manifests a passion for excellence, teamwork, leadership, and responsibility.

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