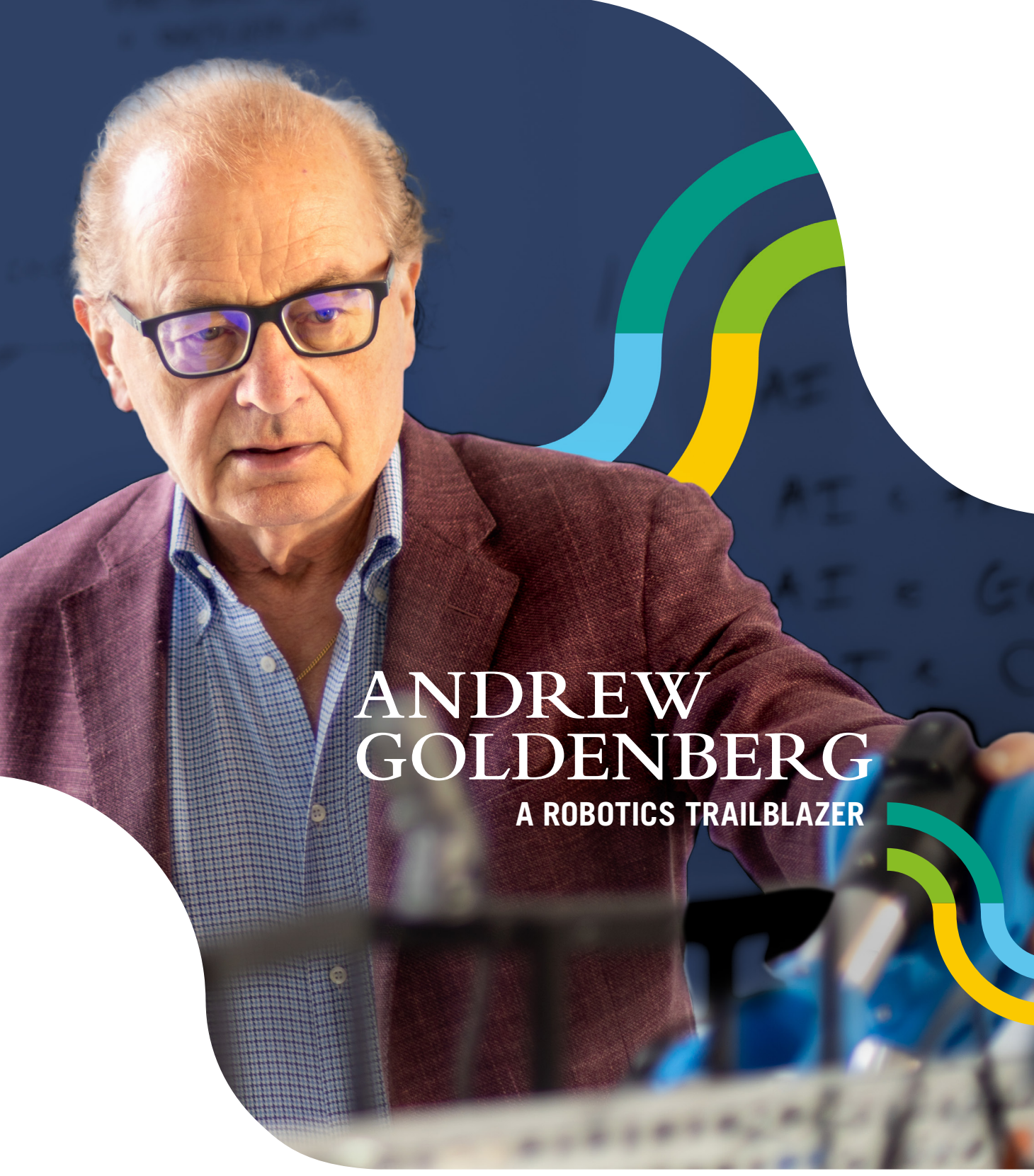


ANDREW GOLDENBERG

A ROBOTICS TRAILBLAZER

UNIVERSITY OF TORONTO | Robotics Institute

ABOUT THE UNIVERSITY OF TORONTO ROBOTICS INSTITUTE

The University of Toronto Robotics Institute holds the largest, most diverse robotics research and training portfolio in Canada. Through strong cross-divisional collaboration, the Institute brings together robotics researchers and graduate students from Engineering, Computer Science, Medicine, and Architecture to develop groundbreaking robotics solutions that solve humanity's most urgent challenges.

> **Having worked alongside Andrew on dozens of robotics and automation projects over the course of nearly three decades, I can readily say that he is the most dedicated, innovative and organized leader I have encountered in my long and accomplished career in the industry. Andrew is a true visionary.**
>
> **Theodor Calinescu**
> President, TC Engineering Ltd.

Canadarm, pictured here, is one of the many groundbreaking robotic systems Andrew Goldenberg helped develop. Canadarm continues to be a vital technology for space exploration, and in 2023, is in its third iteration. (Photo: NASA)

In 1982, Professor Emeritus Andrew Goldenberg became the first robotics professor at the University of Toronto's Department of Mechanical & Industrial Engineering. Goldenberg would go on to become a robotics trailblazer in academia and industry and drive robotics breakthroughs in research, development and job creation.

THE RELUCTANT PROFESSOR

In 1975, a year before **Andrew Goldenberg** received his PhD from the University of Toronto, he worked at SPAR Aerospace (now MDA) developing controls for the first Space Shuttle Remote Manipulator System. This system was later known as Canadarm – Canada's most famous robotics achievement, and one that supported U.S. space shuttle missions for over 30 years.

Canadarm was the first space robotics program of significance in Canada at the time and, as a result, would change the course of Goldenberg's career. According to Henry Kaupp, a deputy branch chief in NASA's Automation, Robotics and Simulation Division, "It was a brand-new design. No one had ever done this before."

Canadarm garnered significant media attention and, consequently, in 1981, a company from Palo Alto, California offered Goldenberg a job. After visiting California, Goldenberg was eager to make the move, but ultimately made the decision to build his career in Canada. Goldenberg's wife Aviva played an important role in this decision. At the same time, Aviva was also building her career and practice as a licensed architect, and preferred to raise their twin daughters in Canada.

"Dr. Goldenberg was my PhD supervisor at the University of Toronto from 1991 to 1995. I chose Dr. Goldenberg as my supervisor because I wanted to be associated with not only the best in scholarly achievements, but also the best in applying scientific knowledge to real-world problems. Dr. Goldenberg is a robotics pioneer well known worldwide."

Guangjun Liu (UTIAS PhD 9T6) Professor and SOTI Research Chair, Department of Aerospace Engineering, Toronto Metropolitan University

At the suggestion of his PhD supervisor, Professor **Edward Davison**, Goldenberg successfully applied to a special NSERC program for a three-year research professorship. Earlier, Goldenberg created and taught the first robotics course at Centennial College in 1977 while working on Canadarm, and realized his passion for teaching.

It was not long before Goldenberg was invited to apply for a newly created robotics faculty position at U of T's Department of Mechanical & Industrial Engineering. Goldenberg still had his sights set on industry and needed some time to consider staying on as a permanent professor. He decided to apply, and in 1982, was offered the position along with lab space and generous funding. That same year, he developed and began teaching U of T's first graduate robotics course and established the Robotics and Automation Laboratory (RAL) that became world-renown in the academic circles.

FROM THEORY TO PRACTICE

Goldenberg was determined to become a leader in his area of research and would expect the same of his students – challenging them to innovate. His approach paid off, and by 1985 Goldenberg was given tenure at U of T, and by 1987, he became a full professor.

At this time, many of his publications were receiving laurels and there was no shortage of graduate students who wanted to work with him. Still, he was determined to bridge the gap between academia and industry. He believed that since his research was publicly funded, he had a responsibility to create jobs, and made this part of his mission throughout his career.

A BIG SURPRISE!

Goldenberg had the production bug, so to implement his theories, he used his industry contacts to hire engineers who specialized in design – but he was in for a big surprise: the engineers told him they could not use his theories. When Goldenberg received this news, he knew he needed to listen to the engineers. He made a decision: he would remain a professor because he enjoyed doing research, teaching and supervising students, but he would also work on developing his technical skill set. How? By learning from the very engineers he hired. And learn he did, which meant his theoretical research became informed by his practical engineering knowledge.

"For over five decades, Andrew has been a visionary academic, entrepreneur, and mentor in robotics and mechatronics. Those privileged to be touched by him have emerged as better engineers, scientists, entrepreneurs and people. Thank you, Andrew!"

Milos R. Popovic
Director, Institute of Biomedical Engineering, University of Toronto
Director, KITE Research Institute, University Health Network

WHEN PREPARATION + EXPERIENCE = OPPORTUNITY

Beginning with Canadarm, Goldenberg was at the forefront of robotics research. By 1992, there was an experimental robotics boom when industry was considering the use of robots for many applications. It was the perfect time for Goldenberg to move into the area of production.

Equipped with his theoretical and practical knowledge, plus his entrepreneurial spirit, he took the consulting company he founded in 1982, Engineering Services Inc. (ESI), and created an industrial production company. As the projects began rolling in, Goldenberg developed robots for a range of industries, including hydro, natural gas, abattoirs, security and defense, healthcare and aerospace.

ACADEMIC + ENTREPRENEUR = ROBOTICS TRAILBLAZER

When Goldenberg's research did not inform development, development informed his research. This reciprocal work excited Goldenberg since he was helping transform industries and create jobs.

The work at ESI continued at a rapid pace and, ultimately, Goldenberg spent 33 years turning ESI into a global robotics leader across sectors. In 2000, he sold part of ESI to a public company in Canada and became President of a buyer's subsidiary. Then, in 2015, ESI was sold to a Chinese consortium and Goldenberg become the Chief Technology Officer (CTO) of the buyer's subsidiary in Toronto. Later, he became the CTO of the buyer that became a public company in 2016 listed in Hong Kong.

Prior to selling, Goldenberg also established Anviv Mechatronics Inc. (AMI) in 2006. AMI developed industrial projects and now operates in the evolving field of AI-embedded robotics.

Goldenberg continued to be an active and successful academic, formally retiring from U of T in 2011 and earning the title Professor Emeritus the same year. Goldenberg says he shares much of his success with his wife Aviva, who always supported and encouraged him throughout his career. In 2023, Goldenberg continues to drive robotics innovation — he leads three start-up companies and has expanded his research into the area of AI-advanced robotics with a focus on personal service robots.

"When Four DRobotics® was just starting, Andrew took the risk to partner with our company on the co-development of an analog lunar/Mars survey sample and return robot. Since then, he has collaborated with us and now advises our company in a variety of areas of robotics, including the development of robot arms and service robots. His trust in Four DRobotics® and his depth of knowledge has made a significant contribution to the growth of the company."

Jeremy James
MScEE SMIEEE Arc Cores Fellow
President & CTO,
Four DRobotics® Corp

GOLDENBERG'S RESEARCH IMPACT BY THE NUMBERS

48
PhD students

67
MASc students

10,500+
Citations

134
Archival journal papers

306
Papers in major conferences

15
Book chapters

105
Patents applied for and granted

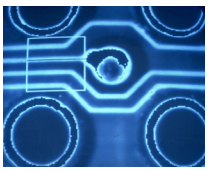
AWARDS AND ACCOLADES

- 2018 Honourary PhD recipient, Technion — Israel Institute of Technology
- 2016 Institute of Electrical and Electronics Engineers A.G.L. McNaughton Gold Medal for Exemplary Contributions to the Engineering Profession
- 2013 Engineering Institute of Canada Sir John Kennedy Medal for Outstanding Merit in the Engineering Profession
- 2010 Professional Engineers Ontario Engineering Medal for Entrepreneurship
- Designated Consulting Engineer in Ontario
- Fellow of The American Association for the Advancement of Science (AAAS)
- Fellow of the American Society of Mechanical Engineers (ASME)
- Fellow of the Canadian Academy of Engineering (CAE)
- Fellow of the Engineering Institute of Canada (EIC)
- Life Fellow of the Institute of Electrical and Electronics Engineers Inc. (IEEE)
- Member of the Professional Engineers of Ontario (PEng)


REQUIREMENTS
NEURAL
NETWORKS
MATH ARTIFACT

FROM PROTOTYPES TO PROGRESS

Andrew Goldenberg's achievements span nearly five decades. His work began during the robotics frontier – a time when Canada became the international leader in robotics with the invention of Canadarm. It was a dynamic time when many companies were interested in exploring how robots could help in the workplace, particularly with high-risk functions that were impossible or dangerous for humans to perform. This timeline captures only a sample of Goldenberg's work, highlighting the many ways he solved real-world problems with groundbreaking robotics solutions.

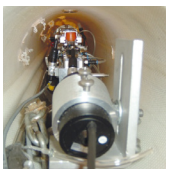


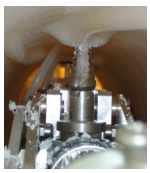
Goldenberg partners with **IBM** to automate and transform the manufacturing process for printed circuit boards — making IBM the first of his many clients.

1985

Ontario Hydro contacts Goldenberg to develop a working prototype of the TreeJib — a robotic arm repair tool mounted on a truck used to safely repair wires in all-weather conditions and reduce risks for hydro workers.

1987 - 1990





Recognizing Goldenberg's work on gas pipes, the **City of Toronto** contacts Goldenberg to develop a robot that can paint the internal walls of water pipes. Goldenberg and his team successfully create this technology in 1998.

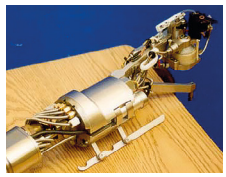
1995 - 1998

1975 - 1981

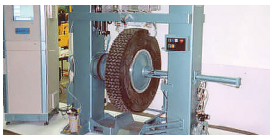
Goldenberg joins **SPAR Aerospace** (now MDA) and contributes to the development of Canadarm — the robotic technology that puts Canada on the map as a space technology leader. Goldenberg helps lead the Canadarm Controls Group to analyze the system's concept, approaches and methodology.

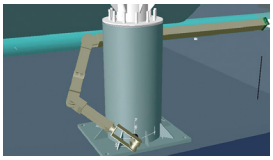
1992 - 1998

Goldenberg works with **Consumers Gas**, **Consolidated Edison Company of New York** and the **Brooklyn Union Gas Company** to create robots that can carry out gas pipe repair work, and Goldenberg and his team develop three new technologies. The first is CISBOT, a remote-operated robot that detects gas leaks and seals joints — eliminating the need for expensive, time consuming and large-scale excavations. For larger main pipes, Goldenberg's group creates a robot with self-propelled wheels to travel through the pipes. Both technologies are still in use today. The third is a keyhole technology used manually to descend and shut down pipes.



Read a detailed history of Andrew Goldenberg's role in developing Canadarm:
www.robotics.utoronto.ca/history-of-robotics/1974-canadarm





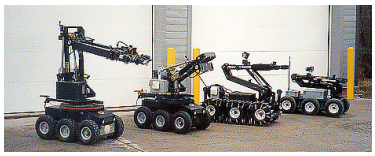
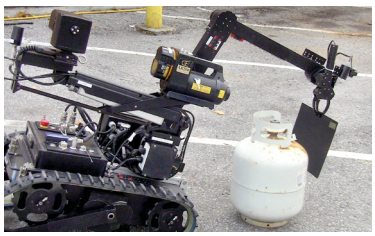

In 1990, Hagersville, Ontario was home to a field of 14 million old tires that went up in flames. A private entrepreneur concerned about the situation collaborates with Goldenberg to create a robotic machine that can determine if a tire can support retreading. To check the tire, the old tire is mounted so that a small robotic arm can rotate inside the tire to map the internal structure.

In the same decade, Goldenberg begins a five-year collaboration with **Atomic Energy of Canada Ltd.** (AECL) that includes the development of several robots to support operations in nuclear energy. The first is the creation of a robotic arm used to maintain tubes in nuclear reactors. The tubes needed to be cleaned internally on a regular basis, but presented significant risks to humans due to high levels of radiation.

Another working prototype Goldenberg creates for AECL is the Long Reach Manipulator to operate in areas where radioactive emissions are higher than permissible for human safety. It includes an ultrasonic scanner used to travel around the legs of the reactor and regularly scan for dangerous defects.

The third collaboration includes the automated handling of employee bio samples so they can be prepared and scanned for radioactivity without human interaction with the biomaterial.

1990s

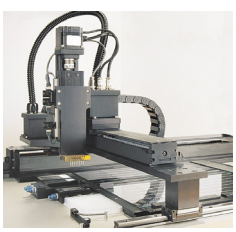
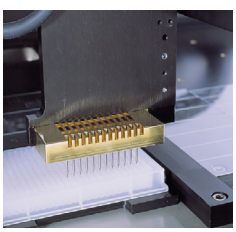



The **RCMP** asks Goldenberg to collaborate with a group of technicians working on Explosive and Ordnance Disposal (EOD) technology. This collaboration is a major project that lasts 10 years and produces a fleet of EOD robots that can climb stairs, extend a camera to a second level floor and X-ray an unidentified object. These robots are used to investigate and, if necessary, dismantle possible bombs — a high-risk activity for humans even in a bomb suit.

1996 - 2006

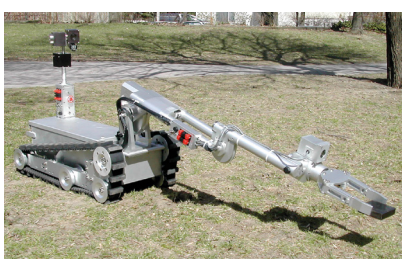
1997

This year marks significant interest in mapping human DNA. The **Ontario Cancer Institute**, affiliated with Princess Margaret Cancer Centre, reaches out to Goldenberg to create a 3D robotic machine that can map and compare healthy and diseased tissue samples. The technology Goldenberg and his team create is so successful that Goldenberg commercializes it through his company ESI and almost immediately sells 60 machines at launch. ESI sold its division to a Canadian public company in 2000.

2003 - 2006

After 9/11, national security is a major concern. Goldenberg is asked by a company in Boston, Massachusetts to develop security robots for defense and crowd surveillance. Goldenberg and his team develop a number of robots, including one that can move along aisles and between rows on planes to conduct interior cabin security checks. Others are equipped with cameras and can climb obstacles to perform surveillance in crowds.



Goldenberg works on three major projects with the **Canadian Space Agency**. The first is an autonomous mobile robot for planetary exploration; the second is a long arm mounted on a spaceship for planetary exploration on the Moon or Mars; and the third is the development of stationary and portable controllers for two robotic arms. The arms are equipped with a drill and suction system to collect rocks and sand. One arm is to be attached to the mothership and used to gather samples nearby, while the other is for surface surveillance and gathering samples.

2009 - 2012

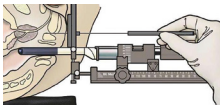
Goldenberg's work moves to service robots. He develops UMEBOT (*see left image)*, which is created to travel from one office to another and enables communication through a screen. UMEBOT can be used in conference settings to give people directions, and in hospitals for doctors to speak with patients.

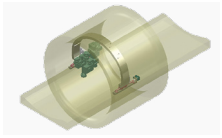
The HRR prototype is created to be a greeter at large institutions and answer visitor questions, such as elevator location and other wayfinding information *(see centre image)*.

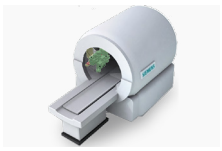
The HRR-B is a mobile bank robot *(see right image)*. It is an integration of the generic service robot platform with a variety of banking business functions added. Instead of talking to a teller, clients can talk to the robot which is capable of walking, sensing, interacting, business handling and dispensing cash.

2010s

1997 - 2017







Goldenberg begins making breakthroughs in healthcare robotics. He collaborates with **Princess Margaret Cancer Centre** and develops two methods of prostate tumour removal to improve on the existing practice of removing the entire prostate. The first method uses a robot to perform the procedure inside an MRI. To do this, it was necessary for Goldenberg's group to neutralize the effect of the magnetic field – a significant milestone at the time.

The second method is conducted with high-intensity focused ultrasound outside MRI rather than with a laser inside an MRI.

Goldenberg also works with **SickKids Hospital** on two projects to conduct more precise and less invasive surgeries for children. The first prototype is a paediatric surgery robot used inside an MRI for conducting bone biopsies on arms and legs.

The second prototype is a Minimally Invasive Endoscopic Manipulator robot used to remove excess cerebrospinal fluid build-up in a child's brain. Supported by a CT scan, the doctor uses a joystick to control the robot.

2023

By launching three more start-ups, Goldenberg continues to develop robots to assist people with daily tasks, such as folding laundry, loading and unloading the dishwasher and washing machine, and making beds.

“

Professor Andrew Goldenberg is one of the key leaders in developing new robotic solutions and technologies. He has a unique ability to use state of the art research and apply it to practical solutions, doing so with great personal skills that lead the engineers on the right pass with confidence.

In recent years, Polygon develops unique technologies to manipulate deformable object for various applications (e.g., panel wiring), which requires a practical approach to the implementation of analytical tools in combination with AI. Professor Goldenberg leads the research on this important front.

Omer Einav
CEO, Polygon

Written by: Joan DaCosta
Photos by: Jaclyn Atlas (page 1), Aidan Samuels (cover, page 7, inside back cover)

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