ROBOT RENAISSANCE

THE RIGHT TOOL FOR THE JOB

From a global division of labor to a robotic workforce

White collar robots

Rise of the robot scientists

Armies become autonomous

PHYSICALIZING THE DIGITAL

From virtual to blended reality

Interfaces become tangible

Every human-machine interaction is a data point

Robots are media

ROBOTS RAISE THE BAR

From being "only human" to new performance standards

Peer review gets automated

Swarming achieves scale

Robots cross the picket line

ROBOTS IN THE WILD

From rigid environments to dynamic infrastructures

Networks are interoperable

Systems self manage

The world is tagged

NEITHER ARTIFACT NOR LIVING BEING

From form factors to phenotypes

AI is rethought, again

The uncanny valley is elevated

A new category of being emerges

OUR ROBOTS, OURSELVES

From mimicking humans to decoding our behaviors

Robot fetishism goes mainstream

Machines write a how-to guide for humans

HUMAN-MACHINE MUTUAL AID SOCIETY

From executing programs to mutual self-improvement

Humans teach robots old tricks

Symbiosis guides evolution

Robots teach humans new tricks

THE FUTURE OF HUMAN-MACHINE INTERACTION

AUTOMATE

AUGMENT

UNDERSTAND

UNDERSTAND

AUGMENT

AUTOMATE

"Klaatu barada nikto!"

– *The Day The Earth Stood Still* (1951)

"The product of the human brain has escaped the control of human hands. This is the comedy of science."

– Rossum, Karel Capek's 1921 play *R.U.R.* that introduced the word "robot."

"Thank the maker!"

– C-3PO, *Star Wars Episode IV: A New Hope* (1977)

"I'm sorry I'm not real. If you let me, I'll be so real for you!"

– David, android child, Steven Spielberg's *A.I.* (2001)

"A robot may not injure a human being, or, through inaction, allow a human being to come to harm."

– Asimov's First Law of Robotics, *Runaround*, 1942

contourcrafting.com

Systems like Contour Crafting, a construction technology developed at USC, promise to revolutionize production of physical buildings and infrastructure.

c-o-n-e.org

CONE is a hybrid teleoperated/ autonomous robotic observatory for remote field biology, from UC Berkeley and Texas A&M University.

robotic.media.mit.edu

Nexi is a dexterous robot capable of a great range of expressiveness designed to more richly communicate stories to human users.

brookings.edu

The introduction of robotic systems into combat is already leading some to speculate that these systems will catalyze a complete reevaluation of war.

spartanburgregional.com

Operating room robots like the da Vinci Surgical System provide human physicians with incredible levels of accuracy.

jcwinnie.biz

Google's project to automate vehicles, based on technologies developed for DARPA Challenge races, will literally put robotics in the driver's seat.

spectrum.ieee.org

The HiBot is a Tokyo-based system designed to inspect multiple powerlines at once.

egmcartech.com

The form factor and dexterity of NASA's Robonaut is intended to allow the system to work alongside human astronauts.

2dayblog.com

ATR and Systec Akazawa's Muu Socia 3.0 is a "communication support" for better physician/ patient interaction.

spectrum.ieee.org

Osaka University's CB2 robot mimics behaviors of human infants.

harpercollins.com

In his book ***Love And Sex With Robots,*** **David Levy** explores our deepening emotional attachment to machines.

cmu.edu

Hideki Koziwa's Keepon robot is designed to investigate the role of movement in communication and is being used in autism research.

pinktentacle.com

Tokyo University of Science's Saya is a robot teacher that expresses six basic emotions.

OUR ROBOTS OURSELVES:

From mimicking humans to decoding our behaviors

An array of emerging technologies are providing us with more insight into ourselves—mind, body, and spirit. From medical scanners to implantable sensors, context-aware computers to obsessive tracking by the "quantified self" movement, rivers of new data are revealing how our bodies and minds work. Once we understand that data—why something is funny, how we learn, what makes us sick—it will be easier to program our machines to interact with us in helpful, natural, and "user-friendly" ways. By sussing out what it really means to be human, we will be better suited to build robots in our own image, or at least program them to be comfortable, and provide comfort, in a human world. Eventually, a "human user manual" may become the essential reference used by robots to understand the wetware that created them.

NEITHER ARTIFACT NOR LIVING BEING:

From form factors to phenotypes

The term "uncanny valley" refers to our human tendency to relate to artificial systems when they resemble humans, until they get so close that they fall just short of the mark. Robots that look almost human are creepy. It may be possible to bridge this barrier, but it may also be that, in general, attempts to build systems that too closely mimic humans may have been a false start. This theme is already emerging in Artificial Intelligence (AI) research and could begin to take hold in next-generation robotics. Over the next decade, robotics approaches will shift toward new and unfamiliar designs that are less informed by popular past images of robots and more by the actual circumstances these systems are designed to handle. Indeed, as stated in a recent Purdue University psychological study of how children relate to robots, we may start to see "the emergence of a new ontological category, neither artifact nor living being."

ROBOTS RAISE THE BAR:

From being "only human" to new performance standards

The old folktale of railroad worker John Henry racing against a steam-powered hammer still exemplifies the anxieties around machines competing for our jobs. And in the Robot Renaissance, these flames will be fanned again. We can no longer judge our capabilities relative to each other. We've watched computers defeat grandmasters in chess, a milestone that many experts thought was decades in the distance. And soon, our job performance will be compared to that of our robotic workmates. In fact, robots may be the ones conducting the reviews. And as we still struggle with teamwork, robots will easily collaborate, share resources, and form swarms to achieve unprecedented scale and complete tasks without human assistance. They'll work 24/7, without sleep and without complaints.

THE RIGHT TOOL FOR THE JOB:

From a global division of labor to a robotic workforce

For decades, the law of comparative advantage has governed economic thinking. At its core is a belief that when an individual, firm, or country is able to produce a particular good or service at the lowest price, benefits accrue to everyone. When we are able to trade goods and services freely, focusing on what one produces most efficiently will bring greater growth across global markets. That's the idea behind a global division of labor—workers in different countries producing at the least cost and highest efficiency. As nimble robots enter our workforce, we'll also be faced with new issues around the human-machine division of labor.

HOW TO USE THIS MAP

This map is a guide to what may happen in our world as humans and robots become colleagues, housemates, and even friends. It's built on a year-long IFTF Technology Horizons Program research effort that included expert interviews, lab visits, and, of course, a deep literature review. The result is a suite of content-rich deliverables, starting with this map. Think of it as a tool to help you hold all of these robotics forecasts in your mind as a single universe. Make your own connections between the forecasts, glean specific insights for your organization and your life, and identify opportunities where you can "make the future."
The map is supported by ten *Robot Renaissance Domain Papers* that further illuminate the areas where robots will likely have the most immediate impact. From there, we will present more provocation from seven additional *Robot Renaissance Perspectives*, mind grenades meant to provoke and inspire your sense of wonder about how life will change as this Robot Renaissance unfolds.

SEVEN BIG FORECASTS:

This map is organized around seven big forecasts. These are the core stories that define the interactions and intersections between humans and machines. Each big forecast is supported with a "from/to" statement, suggesting a dramatic shift from where we are today to where we're going in the future.

SUB-FORECASTS:

Under the umbrella of each big forecast are three or four sub-forecasts, quick-hit forecasts that relate to and expand on the bigger stories.

SIGNALS:

Each cluster of forecasts is connected to signals, early indicators and present day examples that are signposts to the future, categorized by area of impact.

AREAS OF IMPACT:

Radiating out from the seven big forecasts are three rings, or areas of impact, that signify how the robot renaissance will change our lives through increased understanding, augmentation, and automation.

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ROBOTrenaissance

the future of human-machine interaction

In the next decade, we will share our offices, hospitals, schools, battlefields, nursing homes, and even living rooms with a new breed of companion. A robot renaissance is underway.

After decades of hype, false starts, and few successes, smart machines are finally ready for prime time. In some areas, the robots will replace humans, freeing us up to do the things we are good at and actually enjoy. In other domains, the machines will become our collaborators, augmenting our own skills and abilities. The first robot boom was in the 1950s, when factory workers met the first industrial robots. Films like *The Day The Earth Stood Still* and *Forbidden Planet* packed theaters, and tin toy robots delighted kids. And now, as robots move out of the factories and make real a century of science fiction, we will once again see these machines in a new light, and we will also reconsider how we see ourselves.

Of course, visions of the future of robotics could easily veer into dystopia. Hollywood loves a good cautionary tale of robots turning against humanity, taking over the world, and generally wreaking havoc. But as you delve into the specific domains where robots will likely have the most impact, a much richer canvas of possibilities emerges. That is because machines never replace humans but rather change the nature of what humans can do and establish new expectations and standards of performance. Certainly some routine jobs will be taken over by machines. That has already happened and will continue. But the real power in robotics technologies lies in their ability to augment and extend our own capabilities. Our tools change us in unexpected ways, and the next generation of robotic tools can be no different. We will make new robots, but the robots will also make us.

This map, and the associated series of written perspectives, are tools to help navigate the coming changes. As we scanned across ten application domains, seven big forecasts emerged. In the process, we also identified three key areas of impact where the robot renaissance will change our lives over the next decade.

In each domain we focus on three levels of impacts:

1. Robots helping humans **understand** ourselves
2. Robots **augment** human abilities
3. Robots **automate** human tasks

Although this is a convenient framework, the lines are necessarily blurred. For example, machines that automate human tasks frequently also augment our capacities and might teach us a thing or two about who we really are. But considered in its entirety, this map and set of perspectives should only spark excitement, and even cautious optimism, about the possible futures of human-machine interaction. After all, what's more quintessentially futuristic than a robot maid? **Welcome to the Robot Renaissance!**

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FORECASTS

PHYSICALIZING THE DIGITAL:

From virtual to blended reality

Robots are becoming a new platform for content delivery. Much of the information that we have been putting online since the birth of the Internet will find its way out of our screens and into a colorful array of more attractive physical objects with improved interaction and interfaces. The boxy media devices we've been accustomed to will be re-thought in alternate form factors. Such robotic media objects will be much more intuitive, expressive, and engaging than today's stiff screens. Robot pundits could offer commentary on our behavior relative to others, or on complex, citywide patterns of activities like traffic flows, bandwidth use, real-time content analysis, and location-based transactions. They may even create live theater starring your mechanical doppelgänger.

ROBOTS IN THE WILD:

From rigid environments to dynamic infrastructures

In 1923, Swiss architect/urbanist Le Corbusier said, "The house is a machine for living in," and should be designed as such. Indeed, as we begin to share our homes, offices, and cities with robots, our entire built environment will become more machine-like. Robots will move out of rigid structured environments such as factories and laboratories and "into the wild." As a result, we'll have to accommodate their needs. For the near future, robots will count on pervasive wireless networks, ubiquitous charging stations, "robot lanes," and objects tagged with identifiers to help them navigate a world they never made. Of course, re-engineering our infrastructure for a new breed of mechanical cohabitants is also an opportunity to improve things for everyone—robots and humans alike. Eventually, the affordances will outweigh the compromises we make for our robot brethren.

HUMAN-MACHINE MUTUAL AID SOCIETY:

From executing programs to mutal self-improvement

Robots of all kinds will be assisting humans in a variety of tasks: during surgery to collaboratively achieve unparalleled precision, putting students through their paces, or sharing the grunt work of repetitive science experiments. Robots will learn by physically mimicking human actions and behaviors, and getting better with each repetition. But through observation and real-time analysis, they will also evolve new techniques to improve performance. So while we teach the robots to be more like us, there will be no shortage of lessons to be learned from our machine collaborators. Indeed, the most successful human-robot relationships will be those that are squarely symbiotic.