29th Annual INCOSE international symposium

Orlando, FL, USA

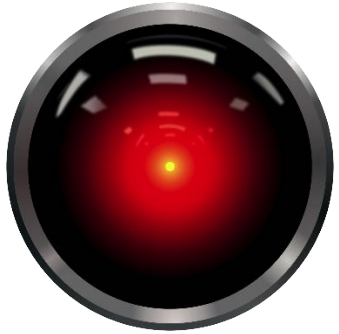
July 20 - 25, 2019

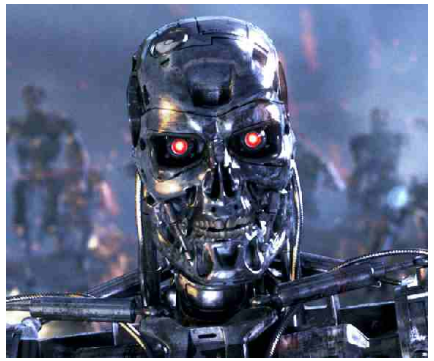
Augmented Intelligence: Combining Model Based Systems Engineering with AI & Machine Learning

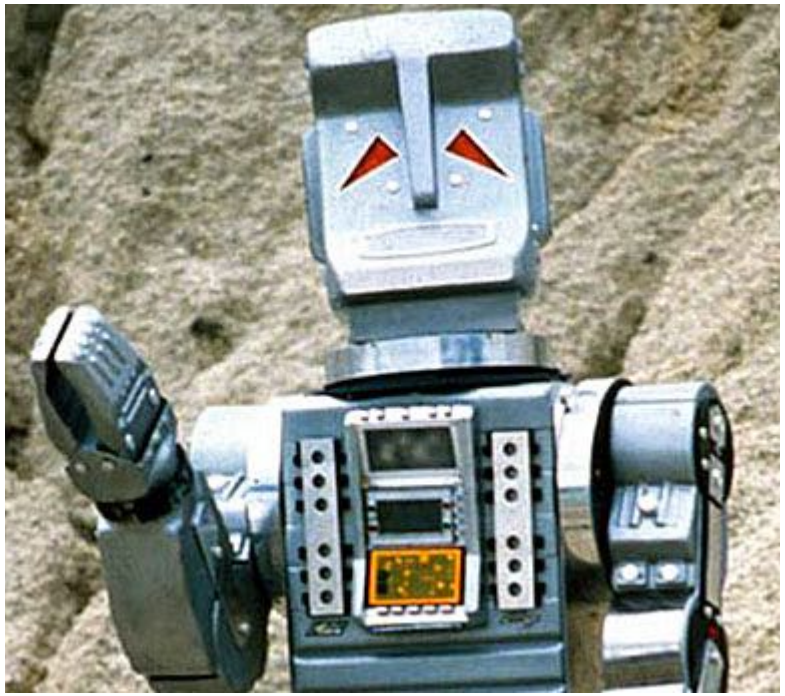
Augmented Intelligence for Systems Engineering

Mark Petrotta
SYSTEM STRATEGY, INC.
Principal Engineer
mpetrotta@systemxi.com

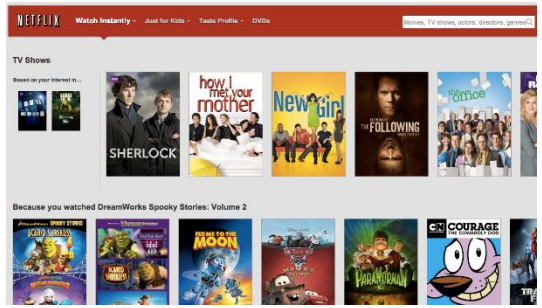
AI We Expected



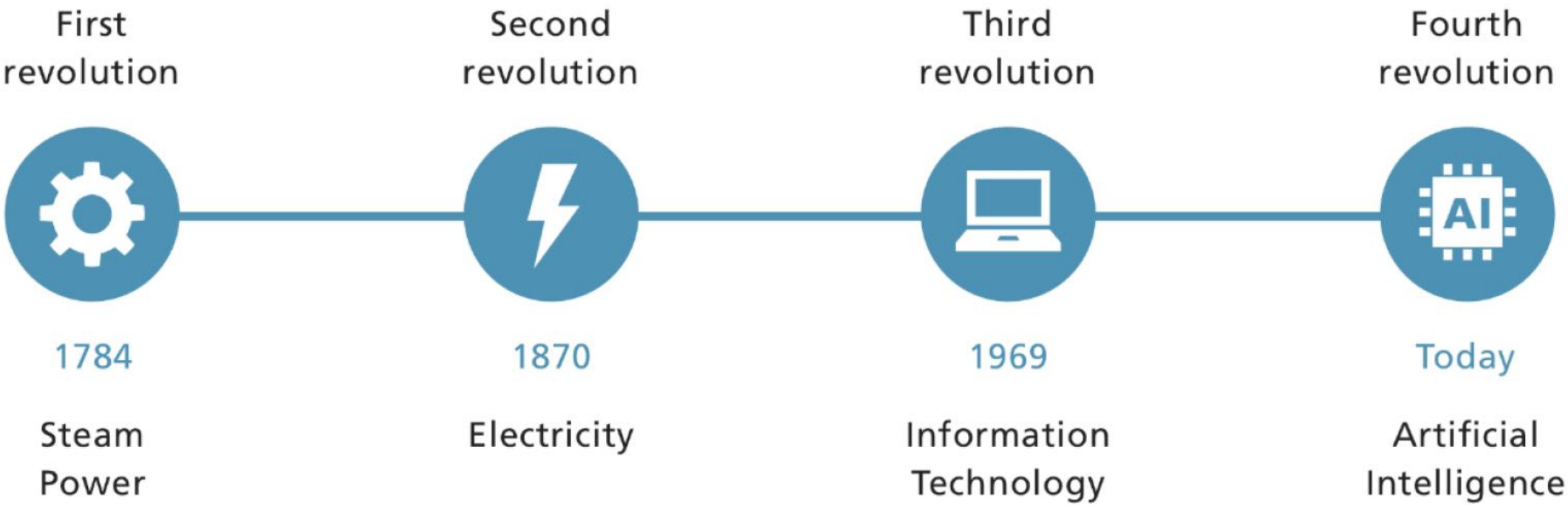




AI We Got



AI and the Fourth Industrial Revolution



+ robotics, nanotechnology, quantum computing, biotechnology, IoT, 3D printing and autonomous vehicles.

But wait…

Augmented Intelligence in SE: Beginnings

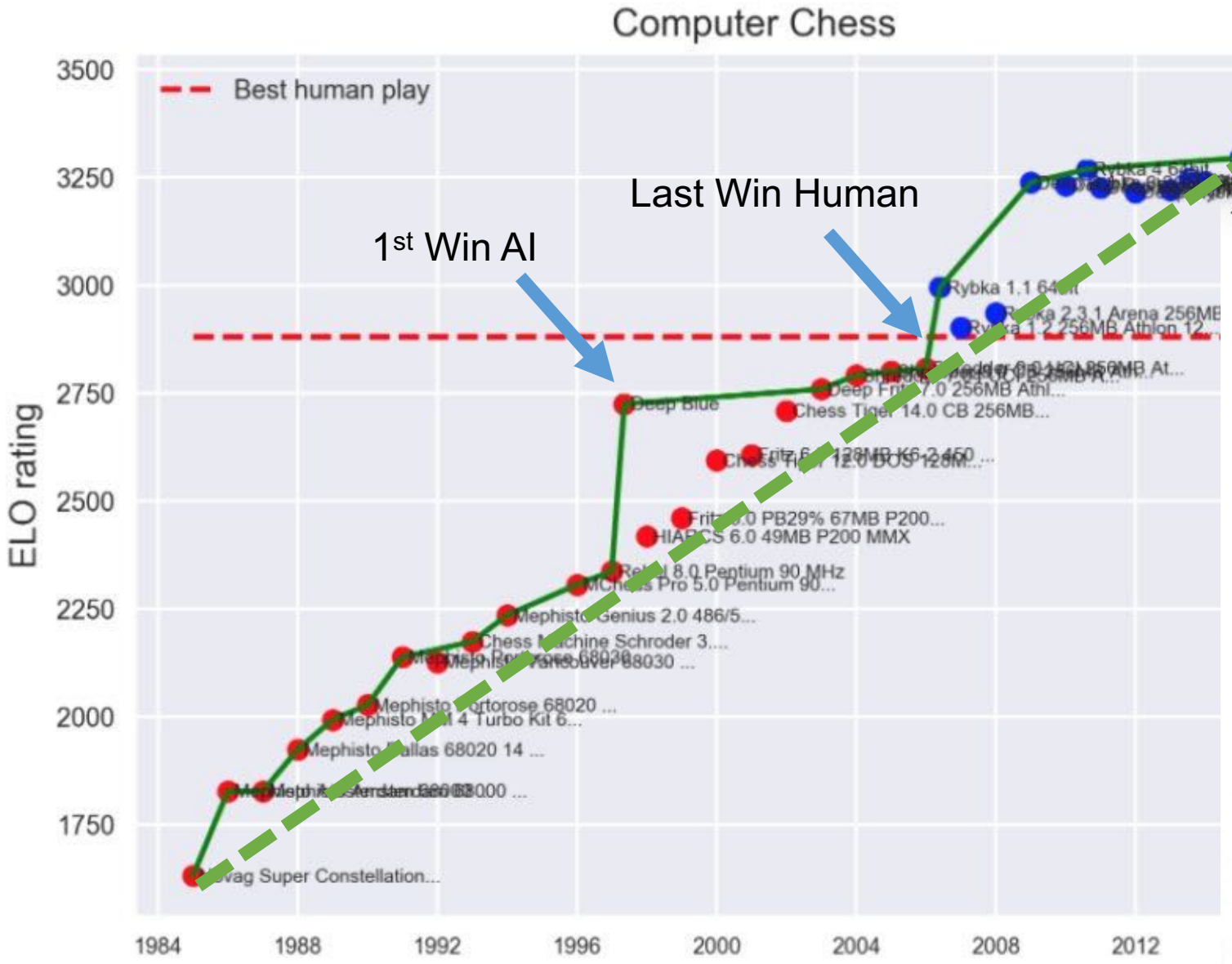
- INCOSE Challenge Team: Augmented Intelligence for Systems Engineering
- Chartered 2018:

  …further the understanding of how computational approaches, such as artificial intelligence, machine learning, and data science, can collaborate with human systems engineers to measurably improve the system engineering effort. The challenge team will seek out approaches that enhance human capabilities in systems engineering.

  http://www.omgwiki.org/MBSE/doku.php?id=mbse:augmented

- *How can Humans and AI Form Effective Engineering Teams?*

Chess: Human vs AI



Kasparov has Deep Blues after losing

Chess champ: I was rooked

By MICHELE McPHEE, K.C. BAKER and CORKY SIEMASZKO
Daily News Staff Writers

The world's greatest human chess player threw a tantrum and cried foul yesterday after being thrashed by a supercomputer.

It took IBM's Deep Blue just 19 moves to defeat world chess champion Garry Kasparov — a stunning finale to an epic week-long battle of man versus machine.

Not mollified by his $400,000 loser's share, Kasparov stormed off like a sore loser after resigning. He later accused IBM of unfairly programing the high-speed computer to beat him specifically.

He suggested that Deep Blue, which was supposed to play on its own, was coached during the match.

He stopped short of saying the computer team cheated.

"I suspect there were things in the match that were well beyond my understanding," Kasparov said. "And when a big corporation with unlimited resources would like to do so, there are many ways to achieve the result, and the result was achieved."

IBM team leader C.J. Tan denied the computer was coached. "Once the clock started, it relied on Deep Blue's system itself," he said.

Kasparov's pal, Michael Khodarkovski, blamed Kasparov's graceless exit on a lack of practice — he said Kasparov had never lost a match.

Kasparov came close to losing to Anatoly Karpov in a 1984-85 championship match that was suspended without a victory on either side.

Kasparov, 34, considered by some chess experts as the greatest player in the history of the game, last year defeated Deep Blue 4-2.

After losing the opening game of the rematch at the Equitable Center in Manhattan, the computer won the second game and fought Kasparov to draws in the next three.

Then yesterday — with a swiftness that stunned the chess world — Deep Blue took advantage of Kasparov's clumsy opening moves and placed him in a no-win situation after less than an hour of play.

Unable to find a way out, Kasparov — playing the black pieces — tipped his king and resigned. He buried his head in his hands and didn't look at IBM's Tan when they shook hands.

The final score was 3½ points for the computer and 2½ points for Kasparov.

Kasparov said he "cracked under the pressure."

"I am ashamed," said Kasparov, who would have won $700,000 if he had beaten the computer.

Patrick Wolff, author of "The Complete Idiot's Guide to Chess," said the world champ "basically cracked."

Kasparov, playing black, used a standard defense known as the "Caro-Kann," forcing white to sacrifice a piece. But for some reason he botched his seventh move and "he became lost," Wolff said.

"This is not a position he wanted to get into," said Ilya Gurevich, a grand master from Manhattan. "It's a pure calculating position where the computer has a big advantage. The computer's strength is tactics."

The computer Kasparov battled was capable of analyzing 200 million positions per second — twice as many positions per second as the IBM model he defeated in Philadelphia last year.

One expert said he was surprised when Kasparov resigned. "It didn't seem lost," said grand master John Fedorowicz of the Bronx, who helped the IBM team prepare its game plan.

At Chess Forum on Thompson St. in Greenwich Village, die-hard chess fans expressed shock at Kasparov's loss.

"This is a historic event," said Mark Wieder, 46, also a computer programer. "The greatest human player of all time lost to a machine."

Chess Forum owner Imad Khachan, 31, said Kasparov was following in the footsteps of other sore losers by suggesting his for didn't play fair.

"This is not uncommon in chess," he said. "When Viktor Korchnoi was playing Karpov in the '70s, Korchnoi made the accusation that the KGB was sending him telepathic messages to destroy his concentration."

LARRY ZUMWALT

RESIGNED: Chess champion Garry Kasparov is disappointed yesterday after losing to IBM's Deep Blue supercomputer. IBM's team leader C.J. Tan (left) denied the computer had been coached, as Kasparov charged after the historic loss in Manhattan. Kasparov will get $400,000 for his efforts.

Artifical intelligence not black and white

DAILY NEWS • Monday, May 12, 1997

FORGET ABOUT THE Garden or the Meadowlands. The real action was outside the Equitable Center on Seventh Ave., where Garry Kasparov, with a name like a hockey player, did battle with Deep Blue, an IBM supercomputer whose name suggests some starlet who did her best work on 42d St. in those halcyon days before Disney.

The scalpers were asking as much as $500 for a $25 seat. "Actually, I'd settle for a couple of hundred," said Ze Ayala. "I have extras."

In the history of New York, there's never been a scalper so hopelessly well mannered as Ze Ayala, Ph.D. Instead of the usual hawker's cry — "Who got tickets?" — Ayala was content to let the business come to him as he burnished his new henna tattoo with a cotton ball doused in lemon juice. "The lemon juice helps the absorption of the dye," he said. The tattoo bore the name of his band, "Flashpot," for whom the tall, long-haired Ayala plays guitar. It should be noted that in lieu of a day job, he works at the Institute of Molecular Evolutionary Genetics at Penn State. His mission wasn't even mercenary; it was professional. He said he wouldn't have sold his own seat for a million bucks.

"My field is artificial intelligence," he said. "And this is the coolest thing to happen in my lifetime."

In such a spirit, the 28-year-old scientist had come to witness the inevitable coolness: Man mangled by Machine.

He couldn't help but root for Kasparov. The sentimental part of him was taken with the charms of obsolescence. But he knew better than to bet against technology.

Kasparov is the best chess player in the world; but unlike Deep Blue, he can also be vain, angry, neurotic, panicked, fearful, in all, human. "Chess is fundamentally psychological," Ayala said. "And that's precisely what Kasparov has working against him."

I asked him how long before Deep Blue is playing lead guitar in his band.

That day will come, he said, and it won't be too long. "You know the band Nine Inch Nails?" he said. "That's all computers. But what you're really asking is: Will a computer be able to write

SEE KRIEGEL PAGE 28

Freestyle / “Centaur” Chess

Rules: {}

0..n

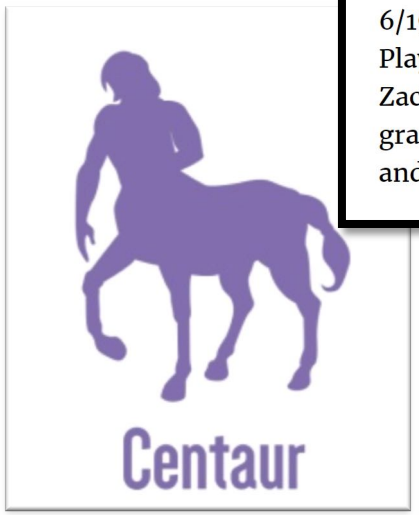
0..n

2005 Freestyle Tournament

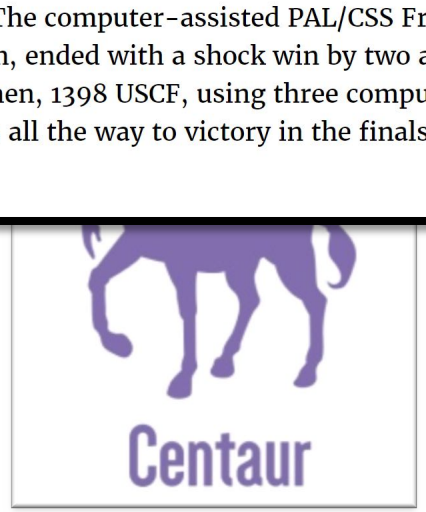
Dark horse ZackS wins Freestyle Chess Tournament

I like it! | 0 Comments

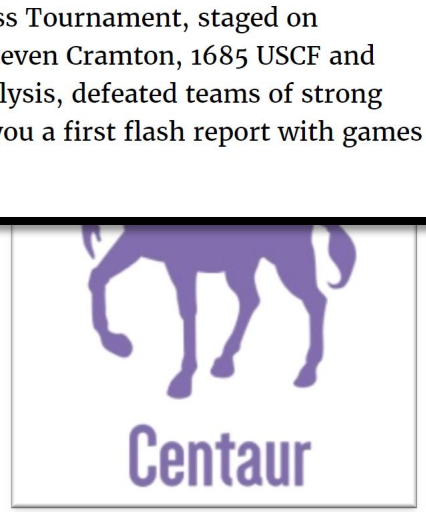
6/19/2005 – The computer-assisted PAL/CSS Freestyle Chess Tournament, staged on Playchess.com, ended with a shock win by two amateurs: Steven Cramton, 1685 USCF and Zackary Stephen, 1398 USCF, using three computers for analysis, defeated teams of strong grandmasters all the way to victory in the finals. We bring you a first flash report with games and results.



GM + 



GM + 



GM + 

"ZackS"

Insights from Freestyle Tournament

Q: What makes for a great freestyle operator?

KASPAROV: Someone who can work out the most effective combination, bringing together human and machine skills. I reached the formulation that a weak human player plus machine plus a better process is superior, not only to a very powerful machine, but most remarkably, to a strong human player plus machine plus an inferior process.

Kasperov's Law:

Weak Human + Machine + Good Process

Outperforms

Strong Human + Machine + Inferior Process

Augmented Intelligence

What is Augmented Intelligence?

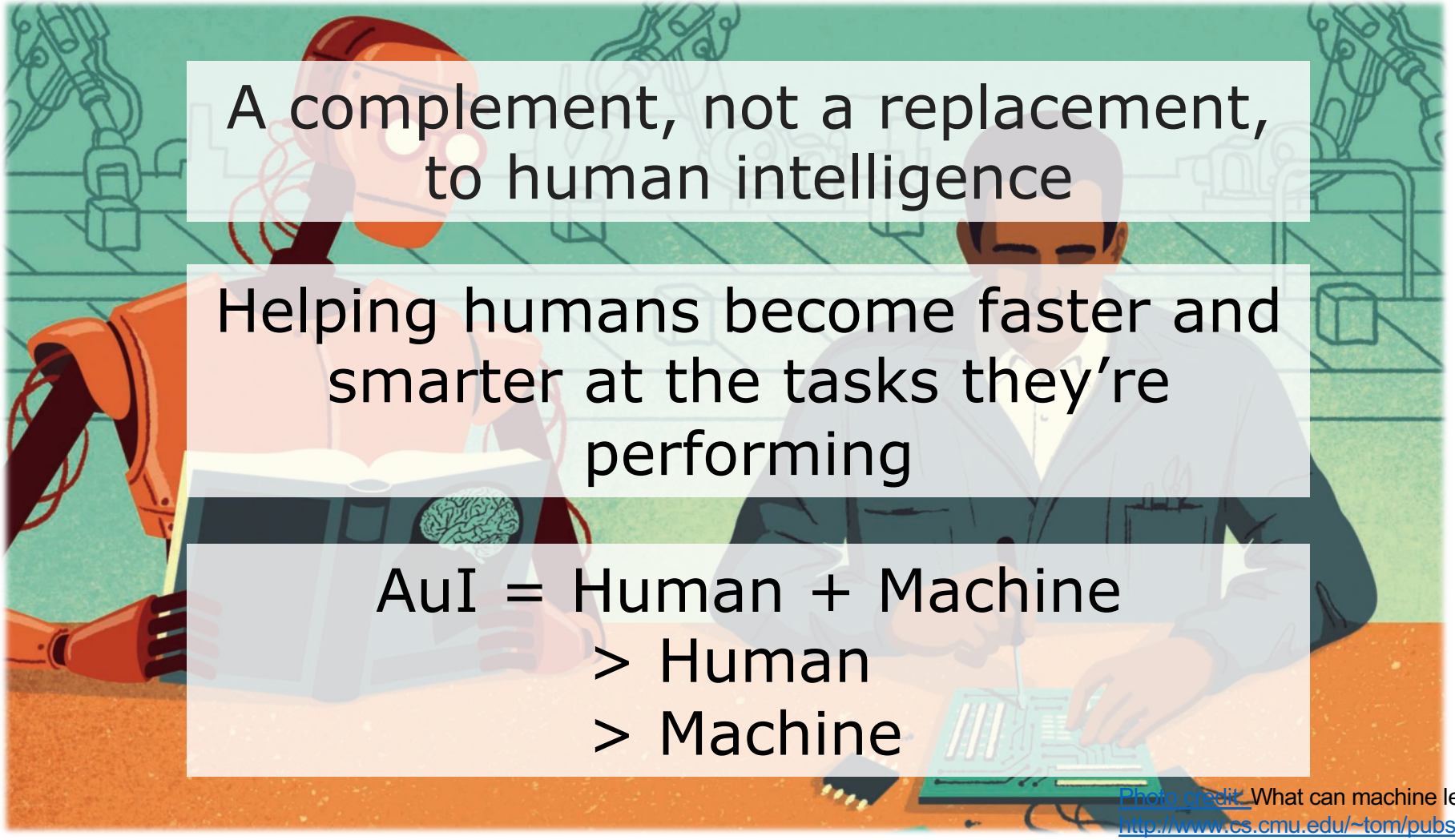
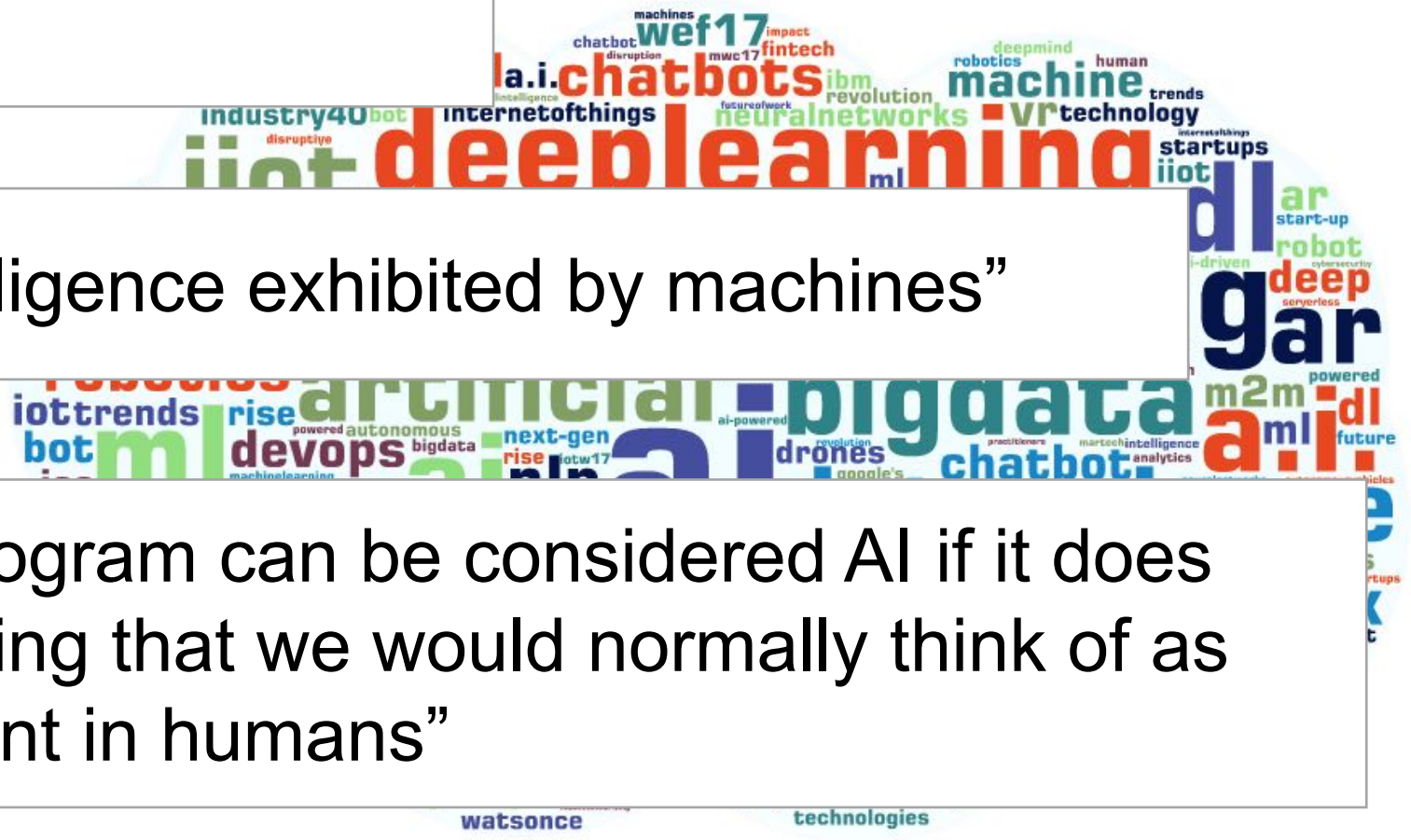


Photo credit: What can machine learning do? Workforce implications http://www.cs.cmu.edu/~tom/pubs/Science_WorkforceDec2017.pdf

What is Artificial Intelligence?

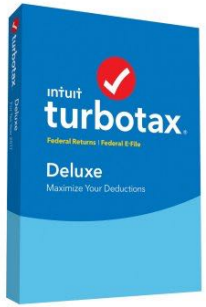
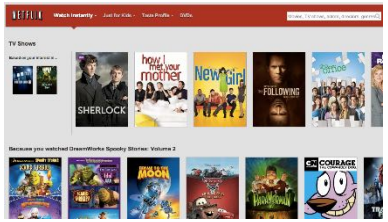
Using computers to solve problems

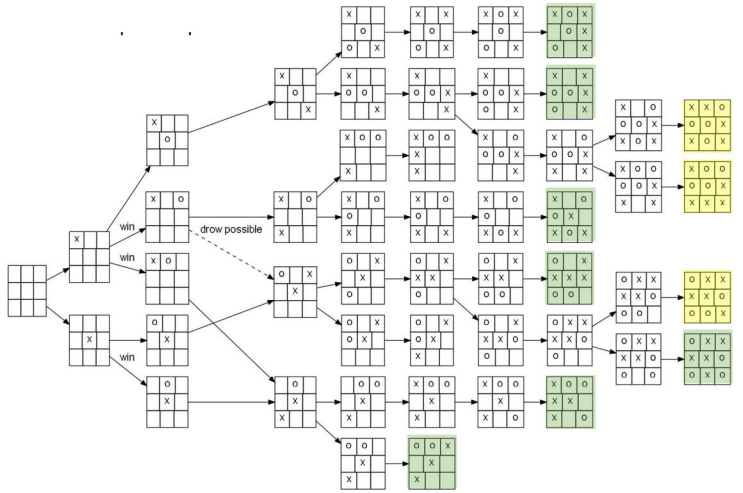
"Human intelligence exhibited by machines"

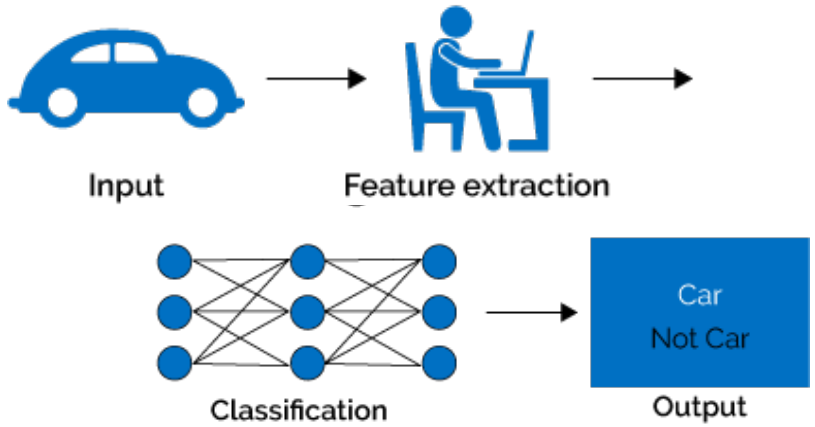


"Any program can be considered AI if it does something that we would normally think of as intelligent in humans"

Two Categories of AI

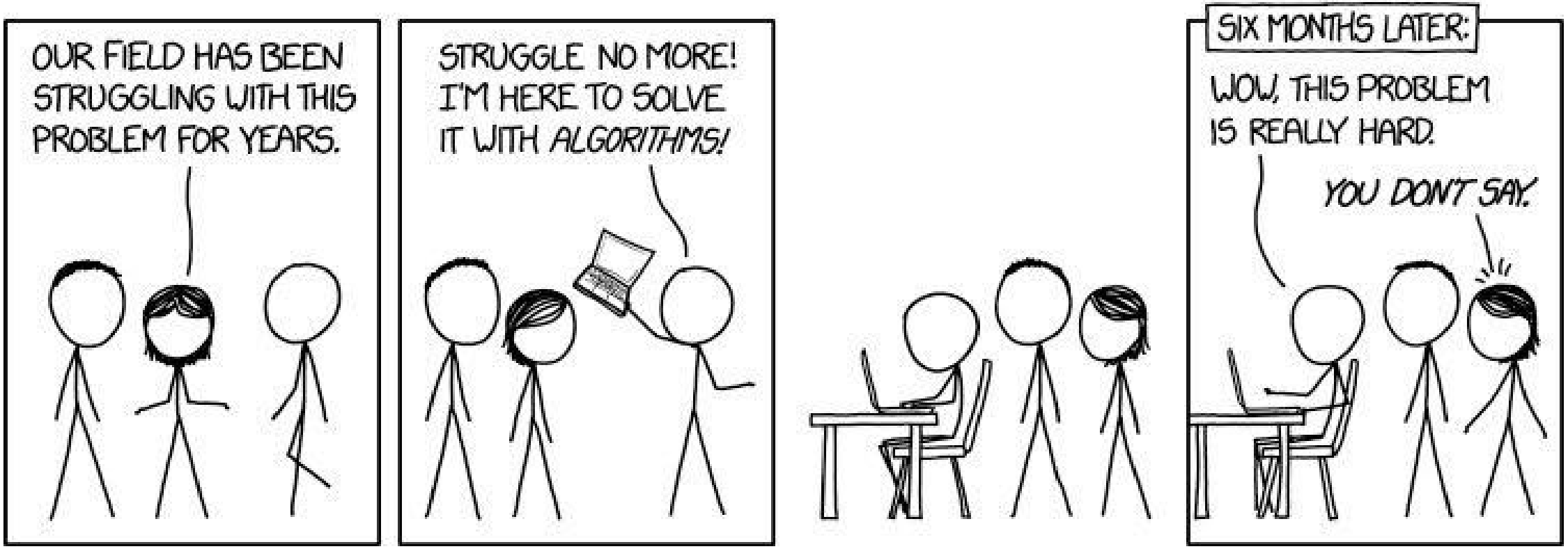
Categories	Example Techniques
"Rules Based" Explicit Knowledge  	• Expert Systems • NLP • Genetic Algorithms • Optimization Solvers
"Patterns Based" Tacit Knowledge 	• Machine Learning • Neural networks • Deep Learning





Augmented Systems Engineering

AI in Systems Engineering

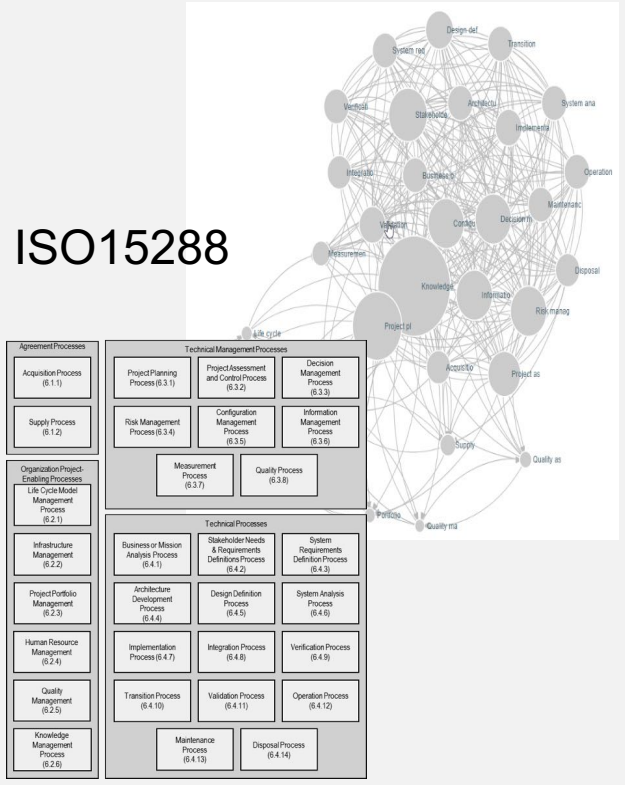


XKCD: Here to Help, https://xkcd.com/1831/

Piecing Together Augmented Intelligence in SE

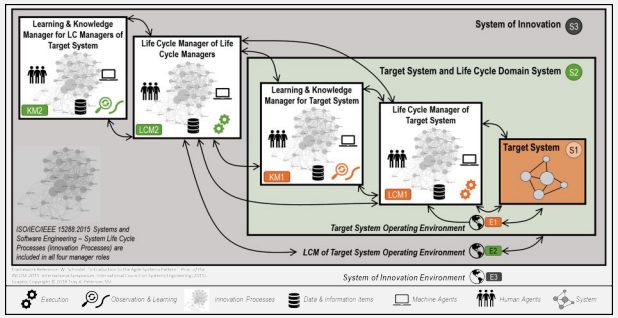
Processes

ISO15288



Framework

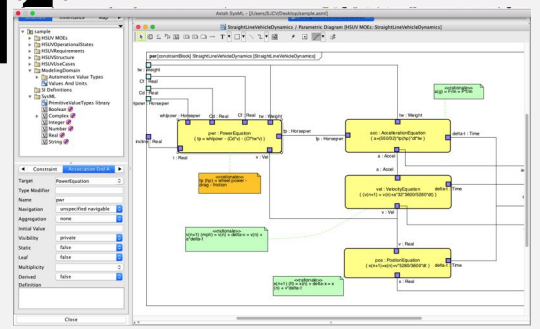
Conceptual Frameworks



Agile Systems Engineering Life Cycle Management (ASELCM)

Patterns

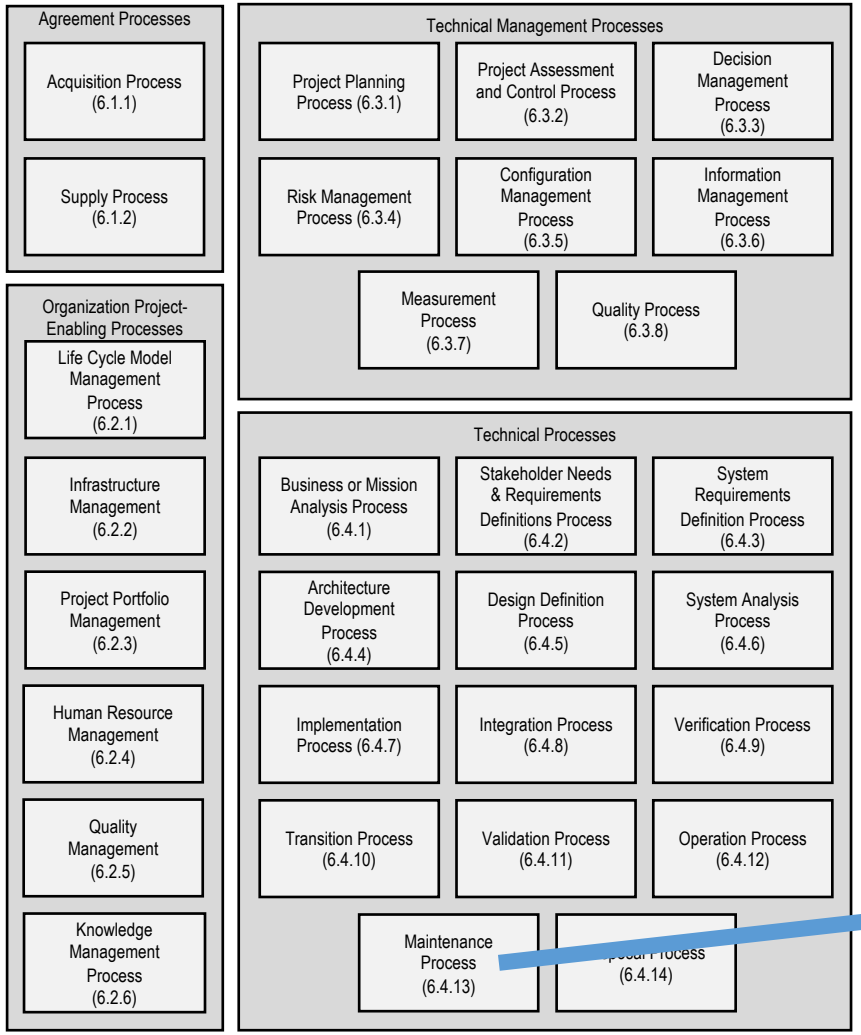
Knowledge & Decision Making



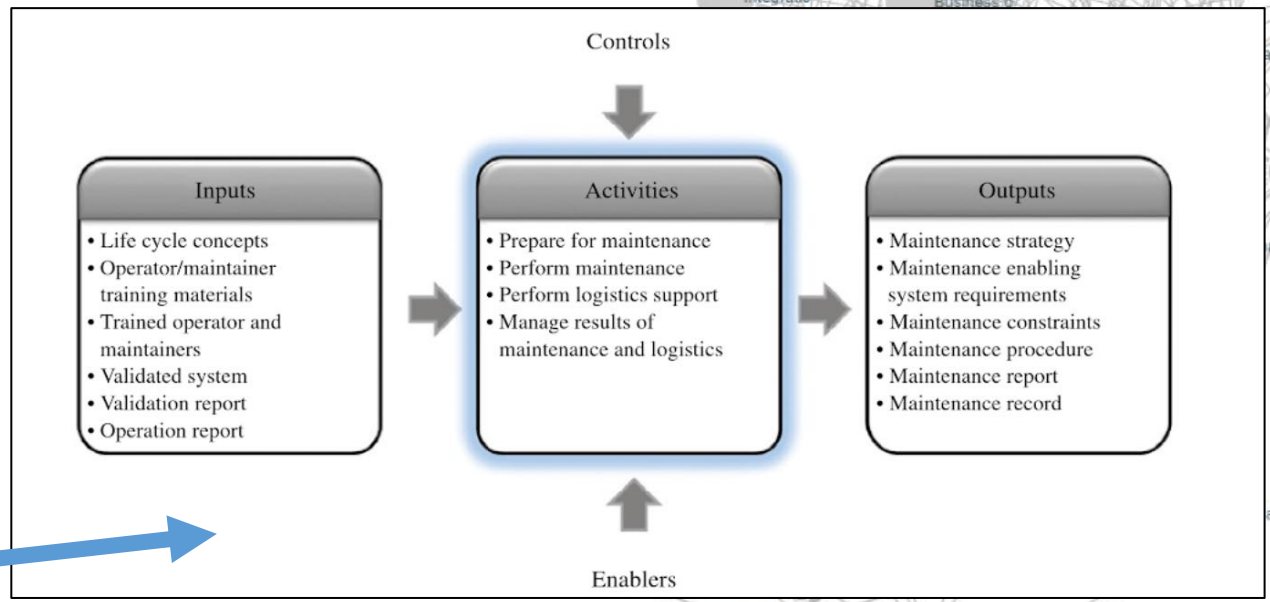
Models
Shared Understanding
Digital Engineering
Trust

How can Humans and AI Form Effective Engineering Teams?

Breadth of Systems Engineering – ISO 15288 Process Areas



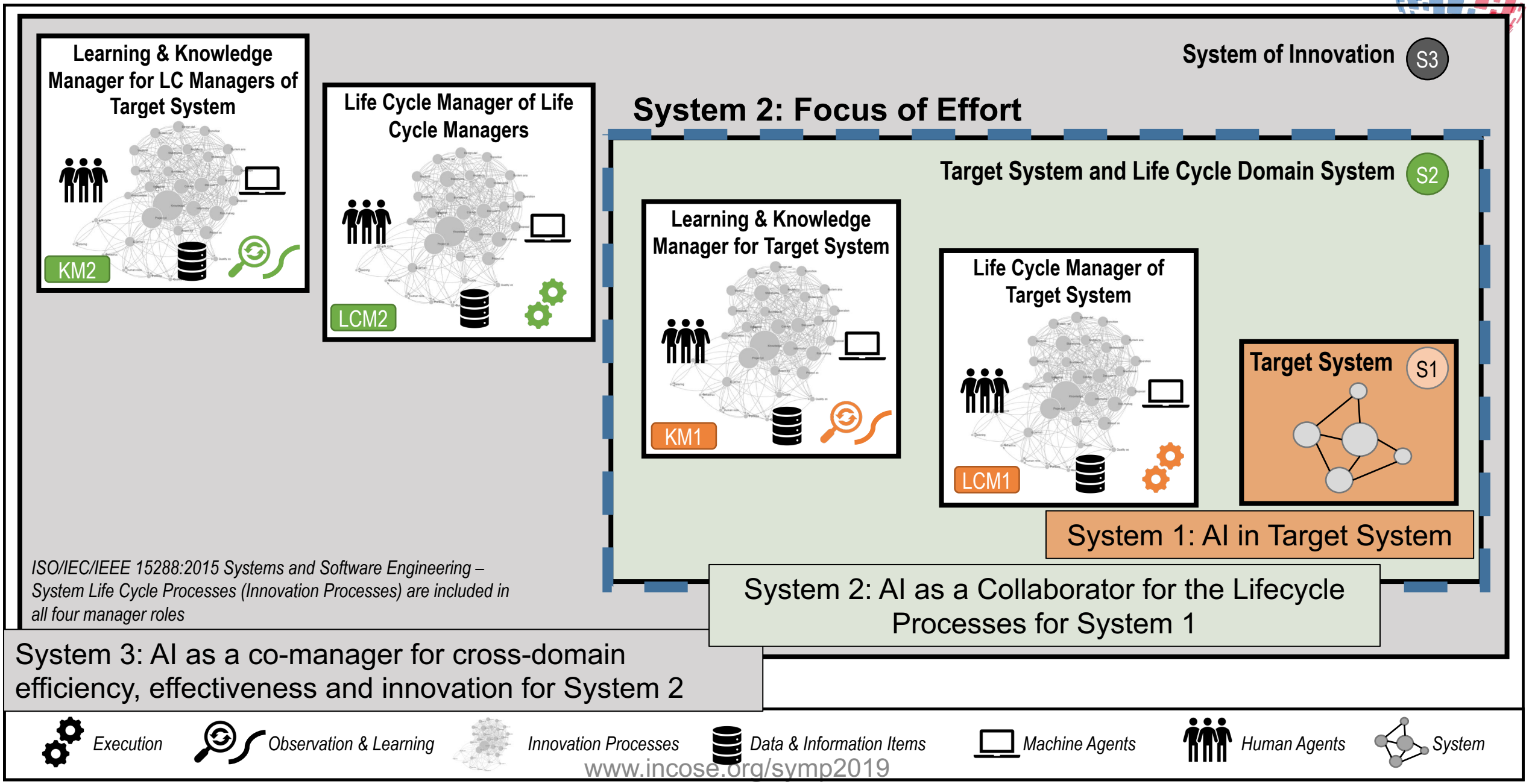
- Each process is defined by a purpose, outcomes, and activities
- Comprises 25 processes which have 123 outcomes derived from 403 activities



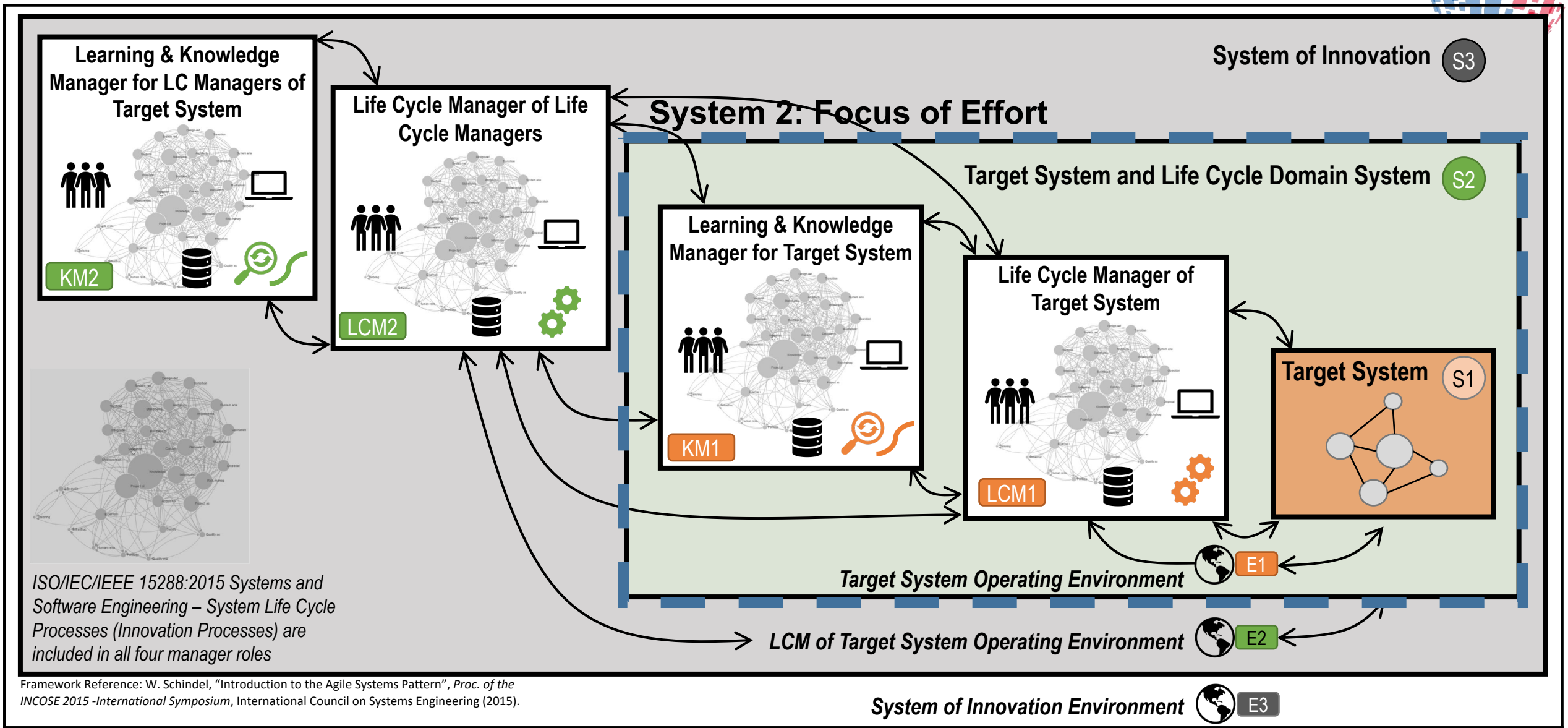
ISO 15288

IPO and Graph of ISO 15288 Process Area interactions from INCOSE Handbook

Conceptual Framework for Human/Machine Teamwork



Conceptual Framework for Human/Machine Teamwork



Framework Reference: W. Schindel, "Introduction to the Agile Systems Pattern", *Proc. of the INCOSE 2015 -International Symposium*, International Council on Systems Engineering (2015).

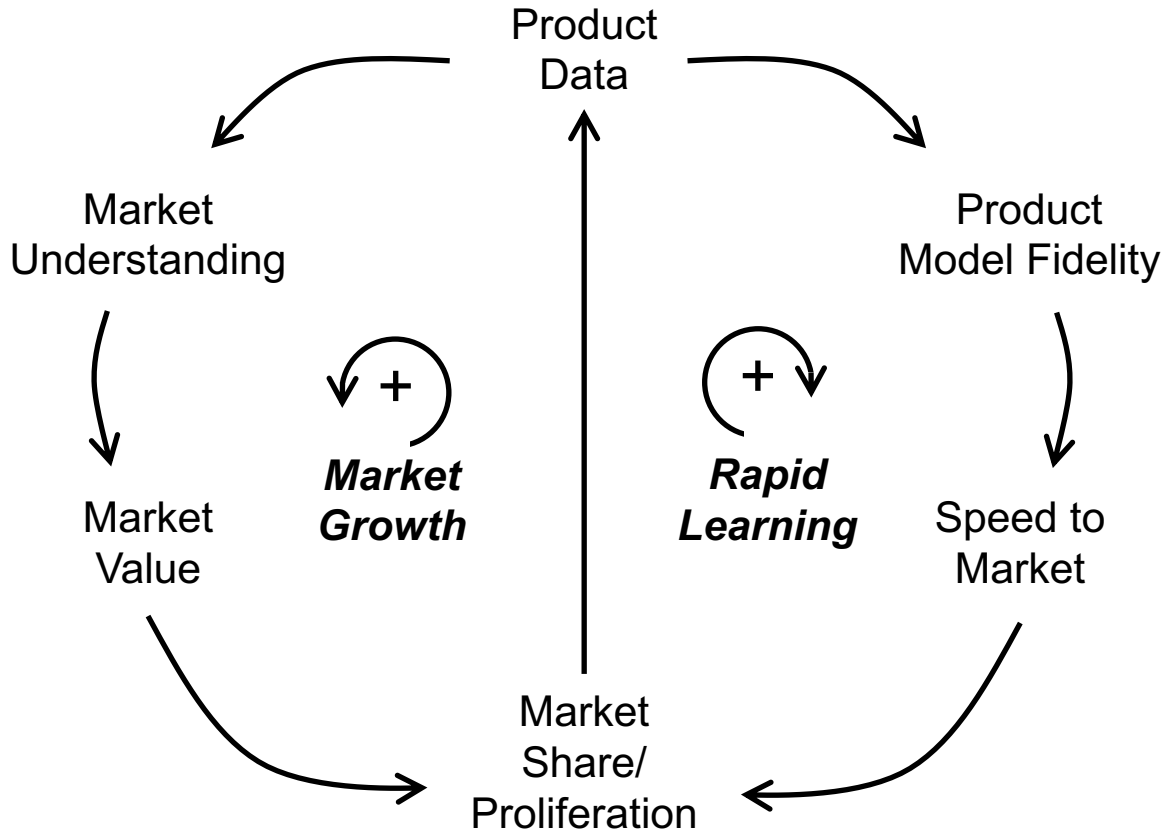
Execution *Observation & Learning* *Innovation Processes* *Data & Information Items* *Machine Agents* *Human Agents* *System*

Models for Knowledge and Decision Making

Both AI and MBSE rely on Models

Model based products get better, allowing them to collect more data, which allows them to build better models, making their products better…

What happens when our models are right?



What happens when our models are wrong?

Models Will Run the World, *Steven A. Cohen and Matthew W. Granade,* Wall Street Journal, *August 19, 2018*

Better Decisions with Human Centered Algorithms

Agency

Reflect the information, goals, and constraints that the decision-maker tends to weigh when arriving at a decision

Perspective

Analyze from a position of domain and institutional knowledge, and an understanding of the process that generated it

Relevancy

Anticipate the realities of the environment in which it is to be used

Objectivity

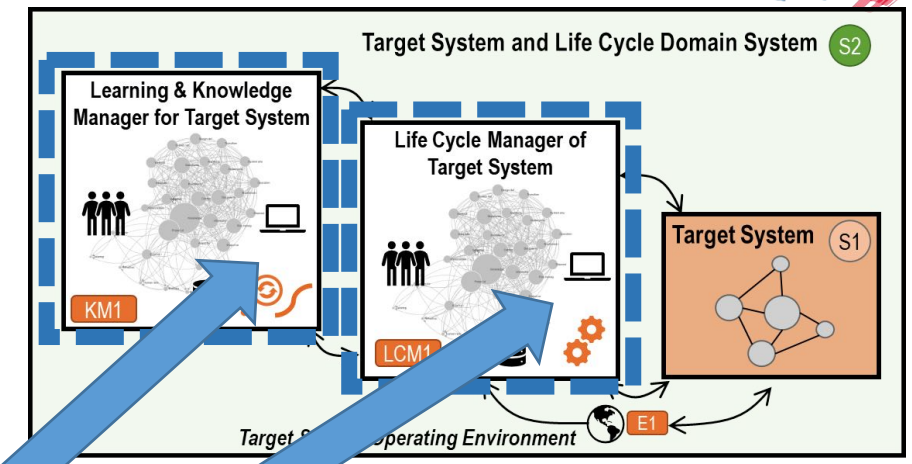
Avoid biased predictors

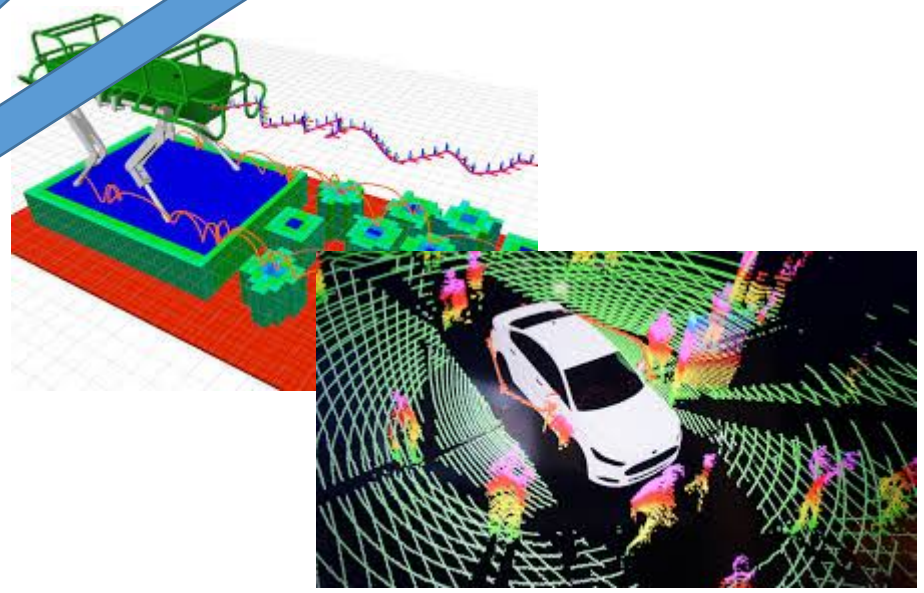
Transparency

Be transparent, peer-reviewed or audited to ensure that unwanted biases have not inadvertently crept in

Candor

Effectively present measures of confidence and “why” messages (ideally expressed in intuitive language) explaining why a certain algorithmic indication is what it is

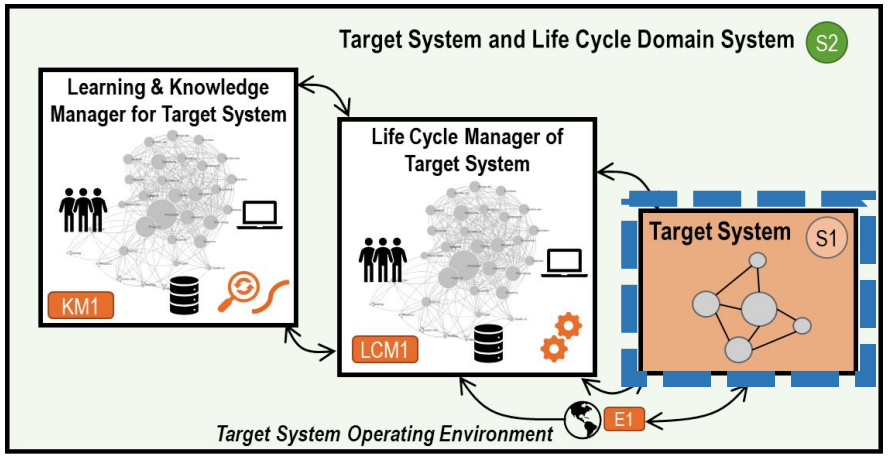


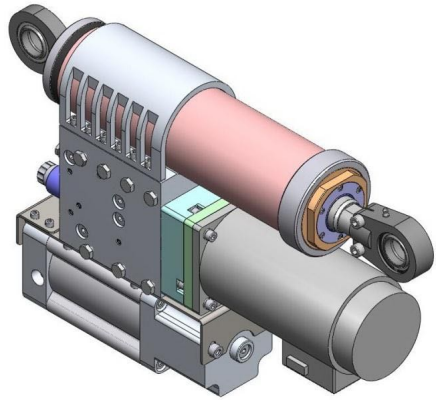


Why artificial intelligence needs human-centered design - Deloitte Review, issue 22

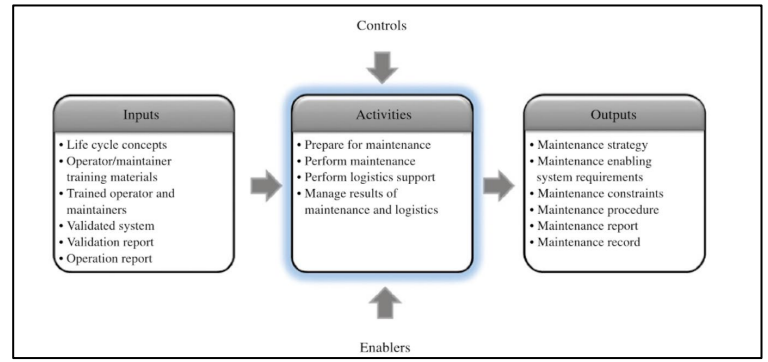
Case Studies of Augmented Intelligence

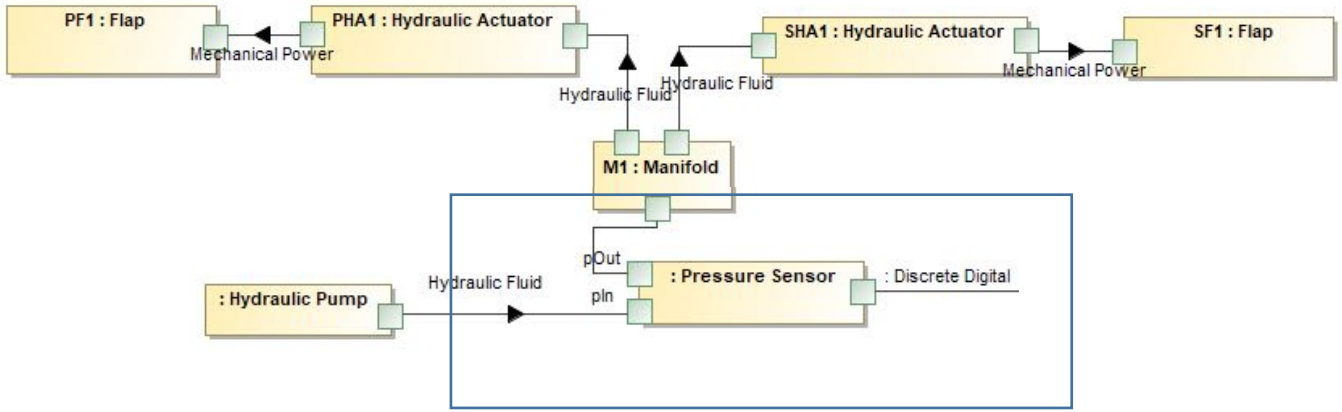
Case Study: Design for CBM





ISO15288/6.4.13



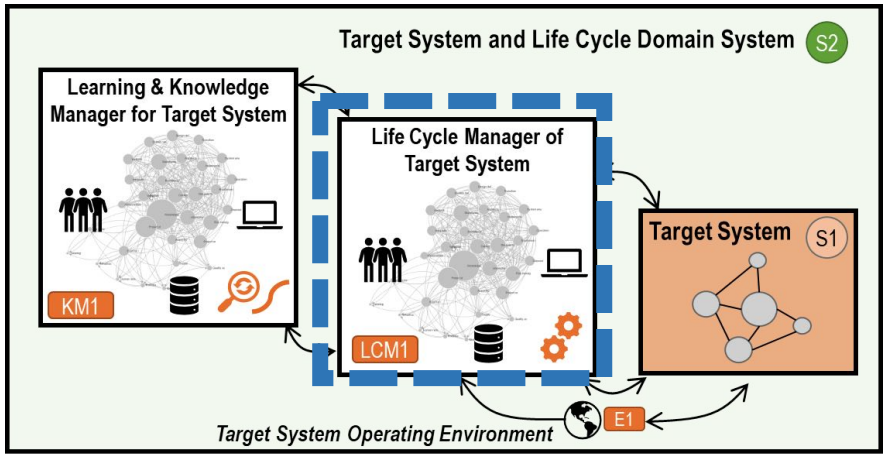


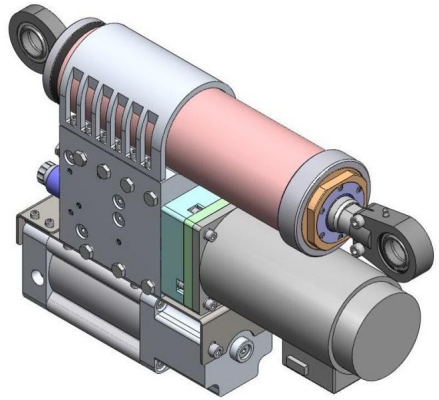
Performance requirement:
Achieve > 90% fault isolation

Constraints:
Sensors can be placed on hydraulic or mechanical connectors

Initial Conditions: 14% fault isolation

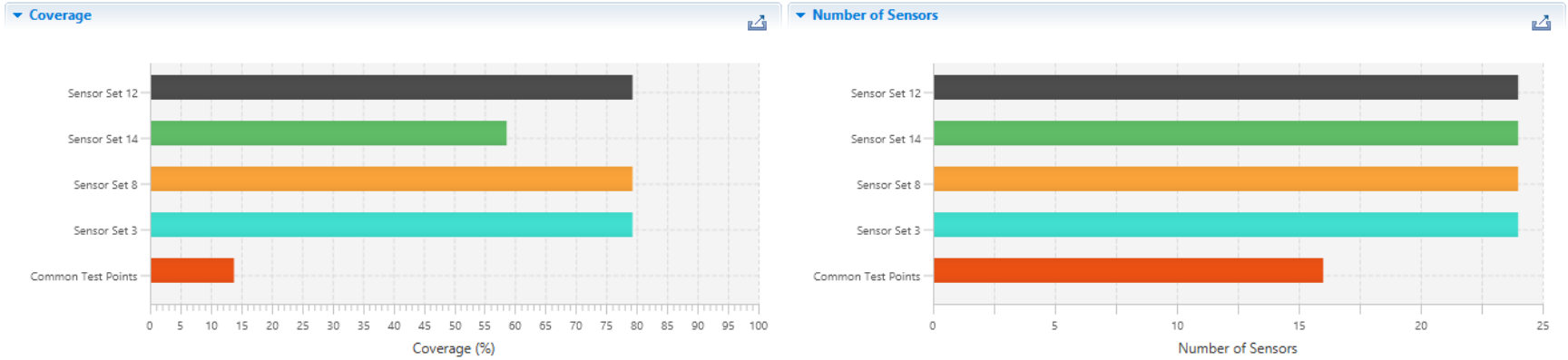
Case Study: Design for CBM



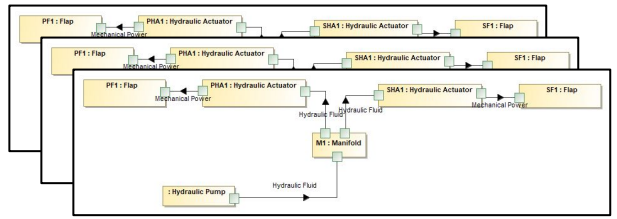


Apply
User: compare sensor sets parameters (coverage, size, weight, cost, reliability) → isolation %

Fault Isolation
User: compare sensor sets parameters (coverage, size, weight, cost)



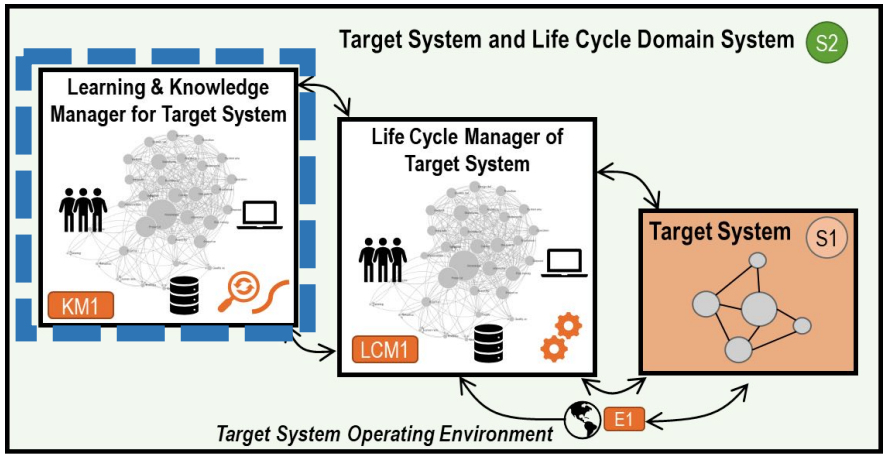
Apply Maintenance Design

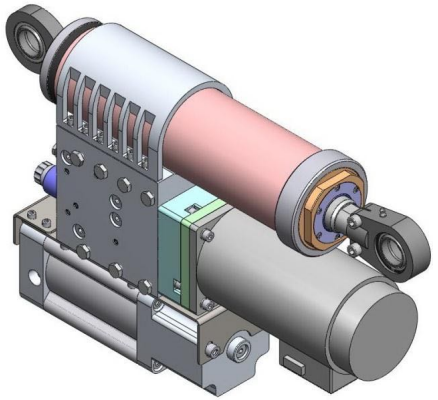


Method: Genetic Algorithm

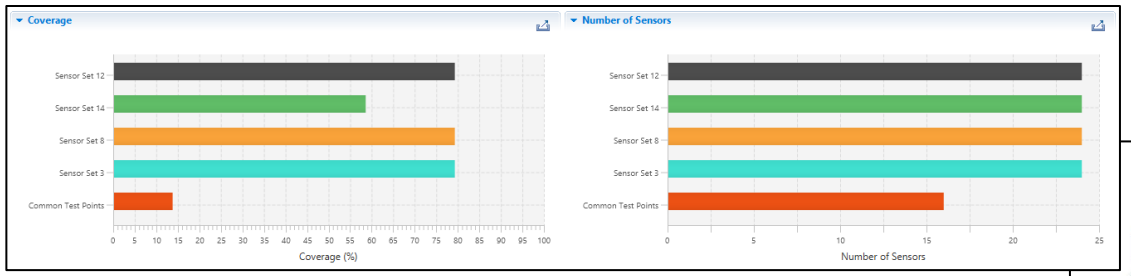
https://www.phmtechnology.com/made/what-made-does/case-studies/design-for-cbm.html

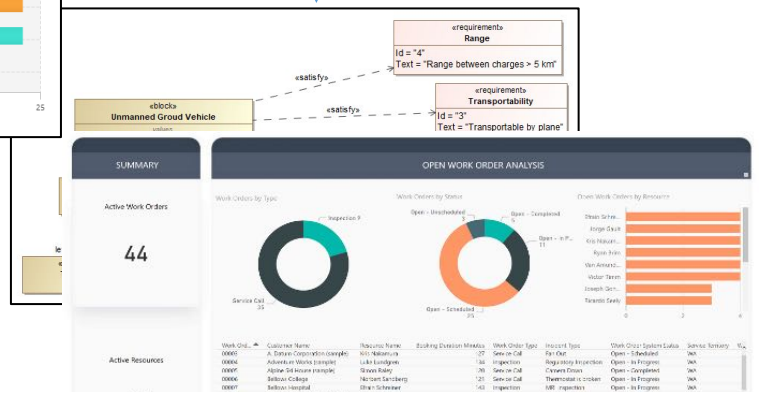
Case Study: Design for CBM





Maintenance Learning System





Learn: Sensor count → Reliability

Observe: Increased failure modes from sensors

Service Reports

https://www.phmtechnology.com/made/what-made-does/case-studies/design-for-cbm.html

How Can SE Form Effective Augmented Teams?

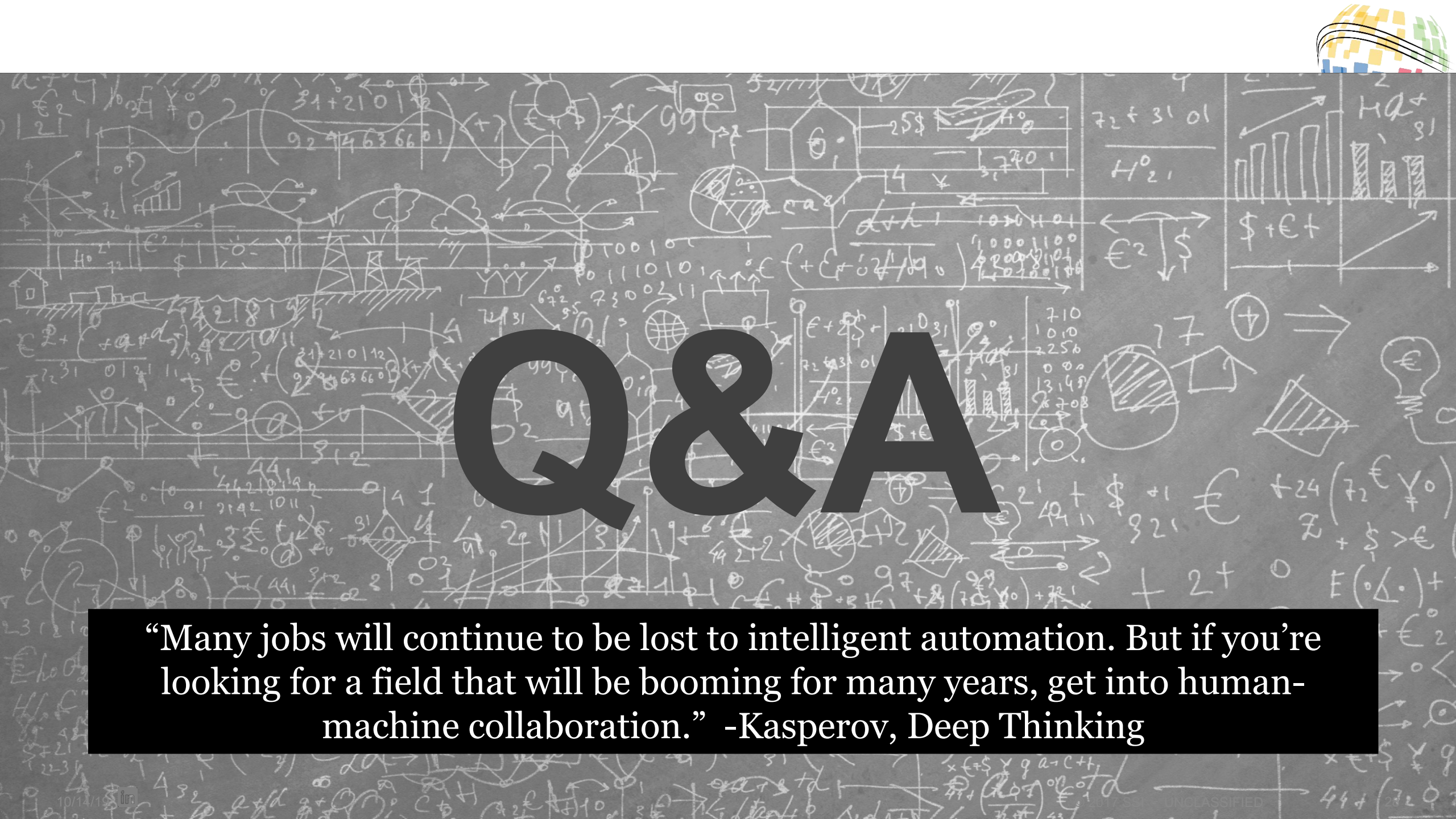
- Effective augmented teams will outperform non-augmented teams
- “Go apply the algorithm” is insufficient, even for simple problems
- Experience in other domains indicate systems engineering will change:

Less

- Direct modeling
- Qualitative assessments
- Disconnected data
- Point-based designs

More

- Value of shared understanding
- Validated models & formalized trust
- Problem space & constraint definition
- Encoded domain knowledge
- Use/reuse of patterns
- Visualizations of state space
- Set-based designs
- …



"Many jobs will continue to be lost to intelligent automation. But if you're looking for a field that will be booming for many years, get into human-machine collaboration." -Kasperov, Deep Thinking

Contact Information

MARK PETROTTA

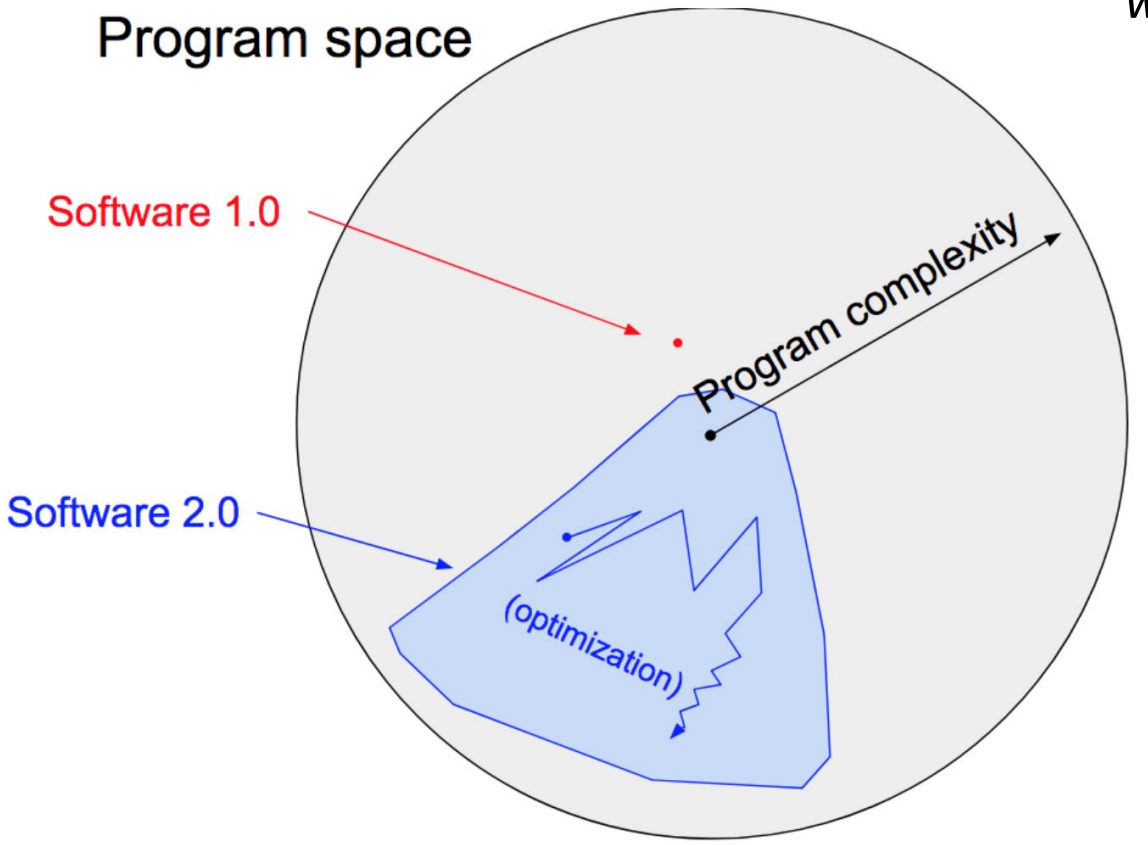
SYSTEM STRATEGY, INC.

PRINCIPAL

mpetrotta@systemxi.com

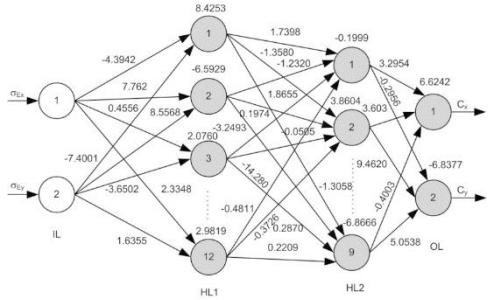
Augmented Intelligence in Software

Software 2.0: Identify subset of program space to search, and use the computational resources at our disposal to search this space for a program that works.



"win a game of Go"

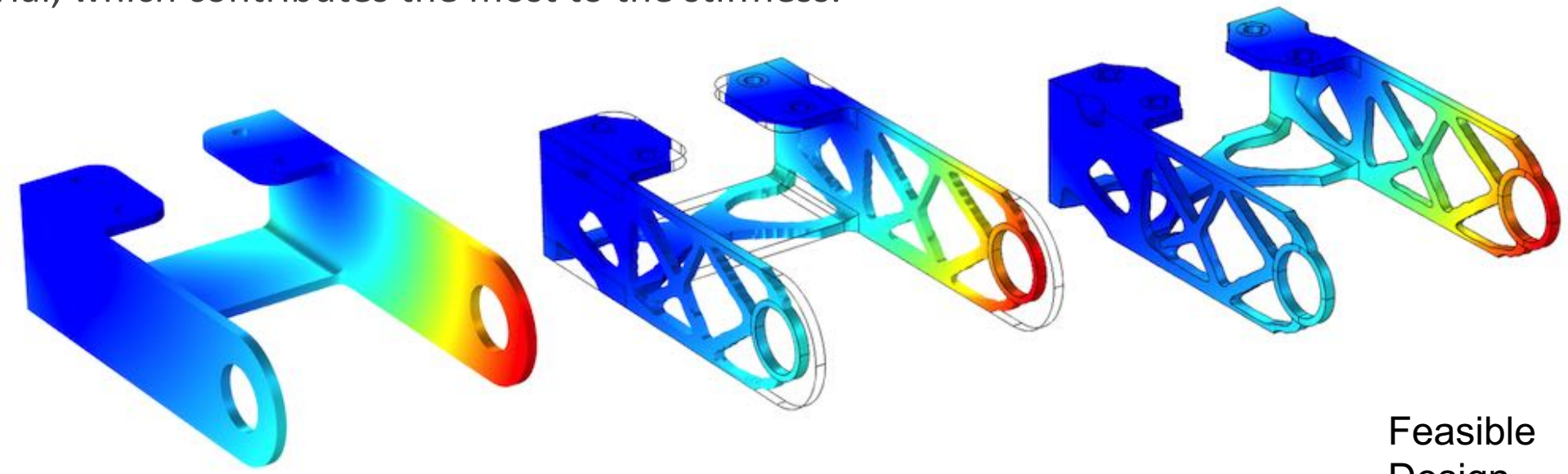
Neural net architecture



Software 2.0, Andrew Karpathy
https://medium.com/@karpathy/software-2-0-a64152b37c35

Augmented Intelligence in Material Science

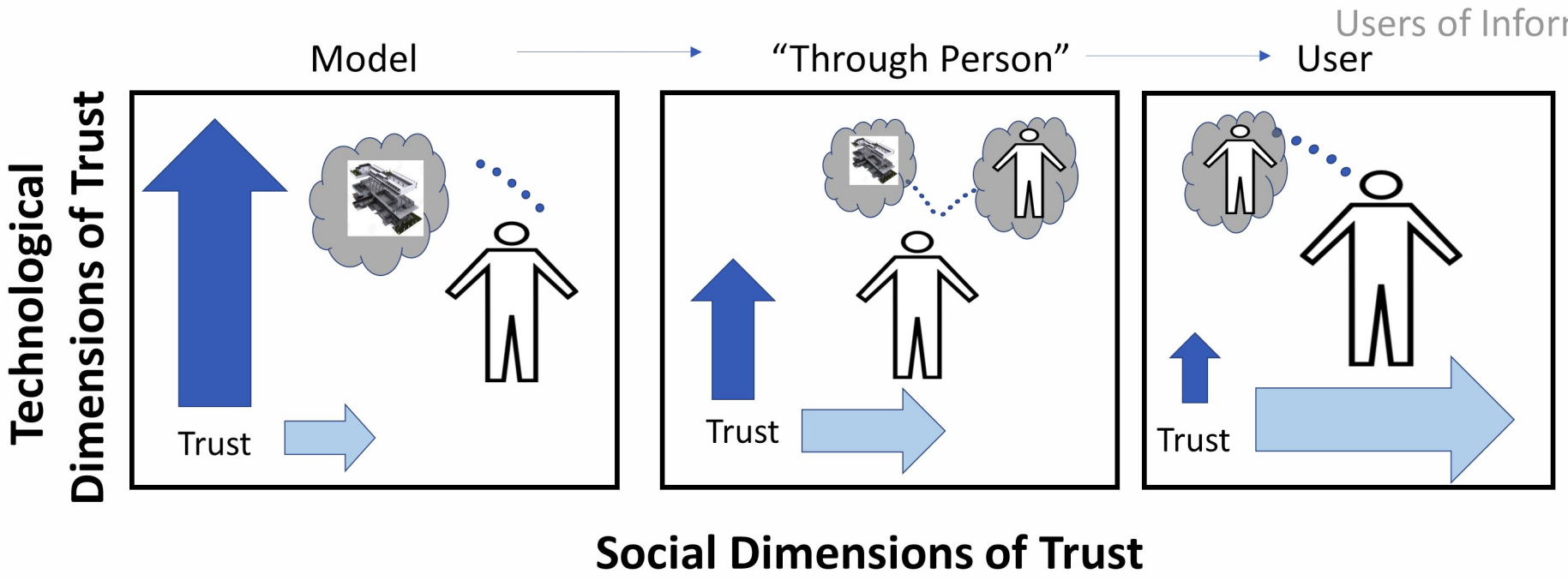
A bracket geometry is topology optimized, leaving only 50% of the material, which contributes the most to the stiffness.



https://www.comsol.com/blogs/performing-topology-optimization-with-the-density-method/

Trust in Models

Through Person Trust Model

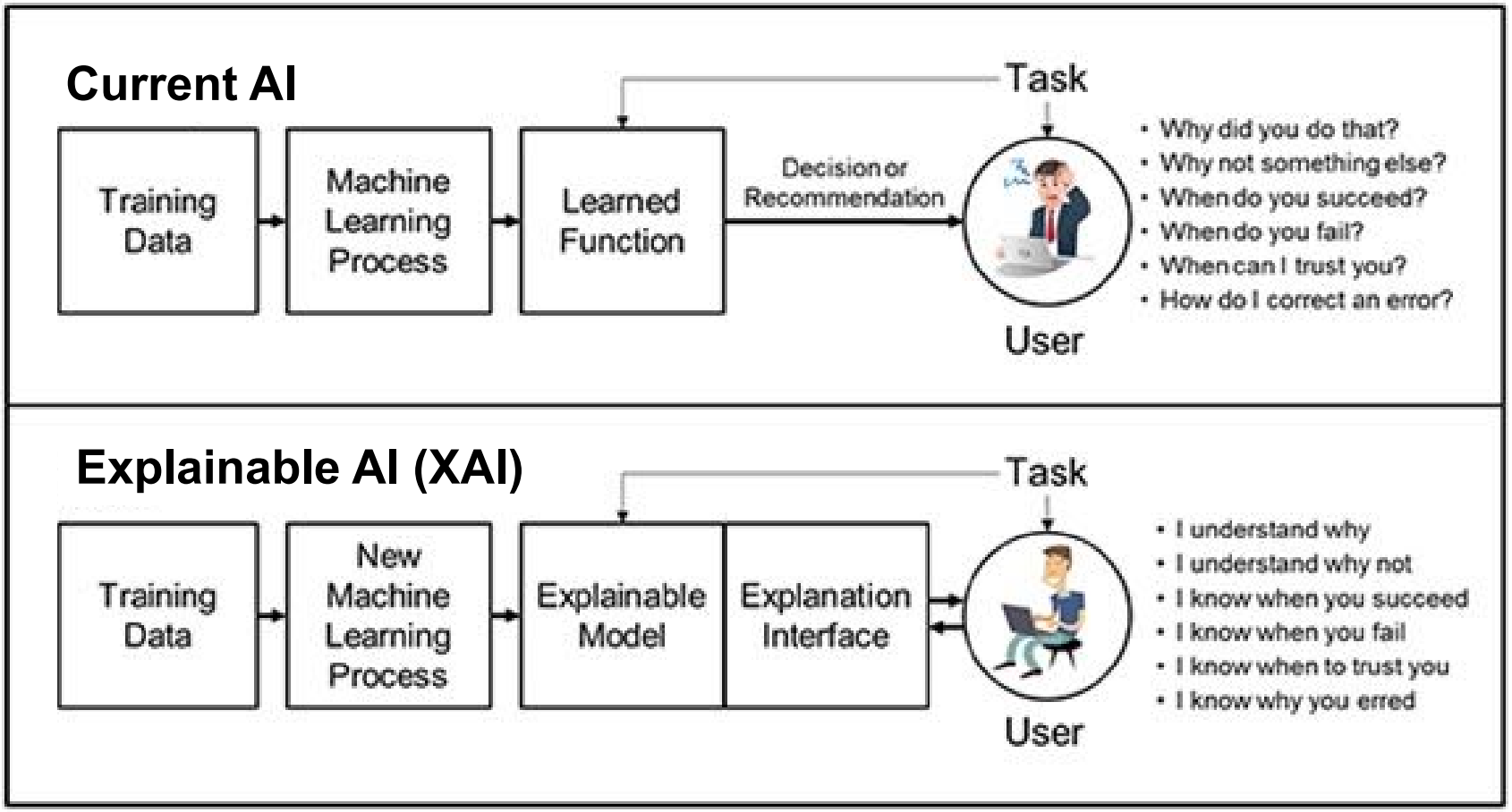


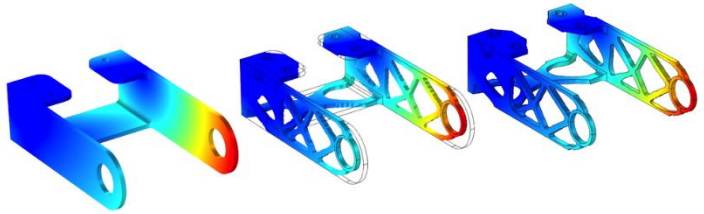
Technical Trust:
Transparency
Code / Data Inspection
Traceability
Visualization

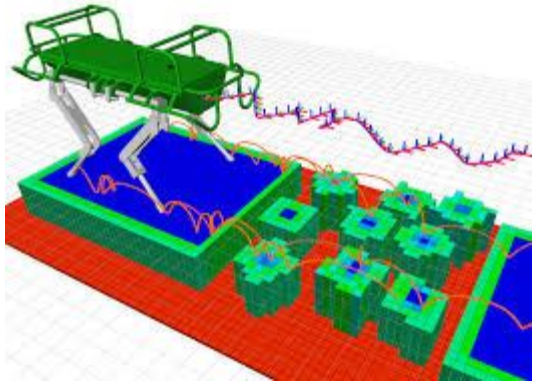
Social Trust:
Credibility
Relationships
Origin
Reputation

Model-Centric Decision Making: Insights from an Expert Interview Study,
Donna H. Rhodes, E. Shane German, Massachusetts Institute Of Technology

Transparent and Explainable Models

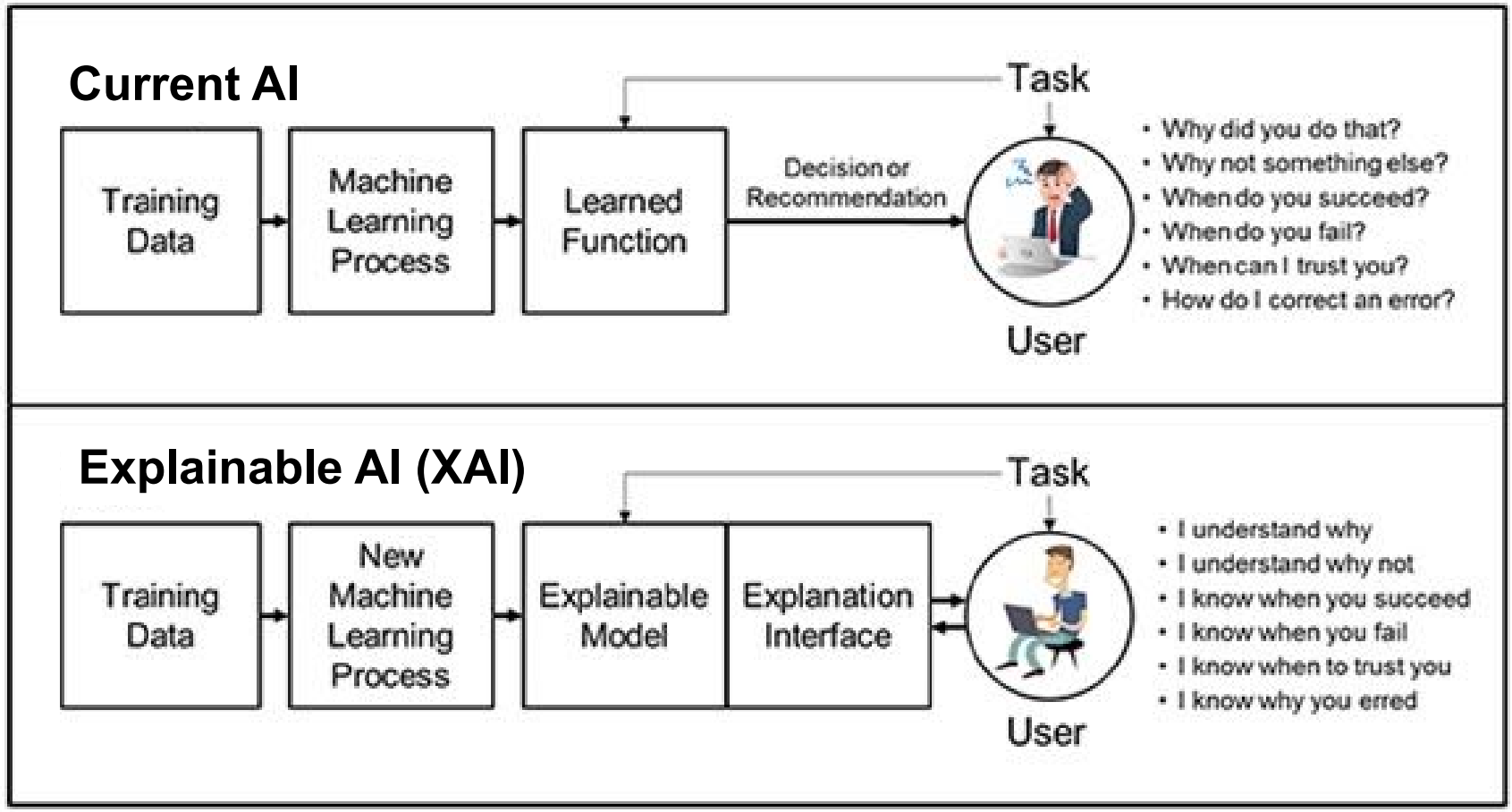


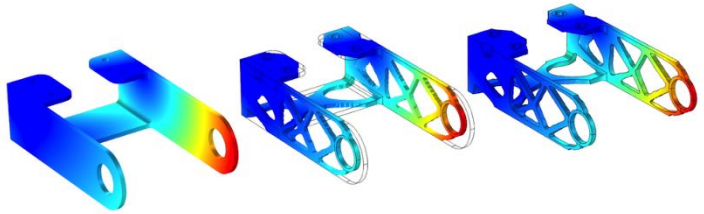


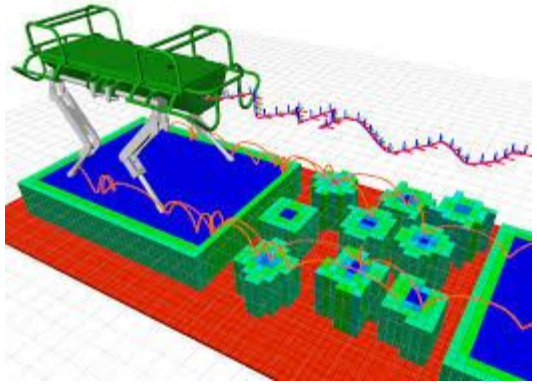


https://www.darpa.mil/program/explainable-artificial-intelligence

Transparent and Explainable Models







https://www.darpa.mil/program/explainable-artificial-intelligence