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Innovation Engineering at Tesla – Agility as a Cultural Practice

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Agile Systems & Systems Engineering Working Group**

Preview

Tesla's engineering practice is pioneering and
radically unique in the automotive sector.

Their pursuit of continual engineering innovation
results in an agile systems engineering approach.

This presentation:

- summarizes Tesla's engineering practice

- features a graphic depiction of that practice

- shows that practice as an agile systems engineering practice

- suggest how that practice can be employed in other sectors.

Why Tesla is Interesting

"Tesla has become the prime innovation driver for the automobile industry, and the pacesetter for the global transition to battery-electric vehicles."

**Timo Daum. Agile Methods on the Shop Floor - Towards a "Tesla Production System"?
Weisenbaum Institut, Berlin, DE. December 2022.
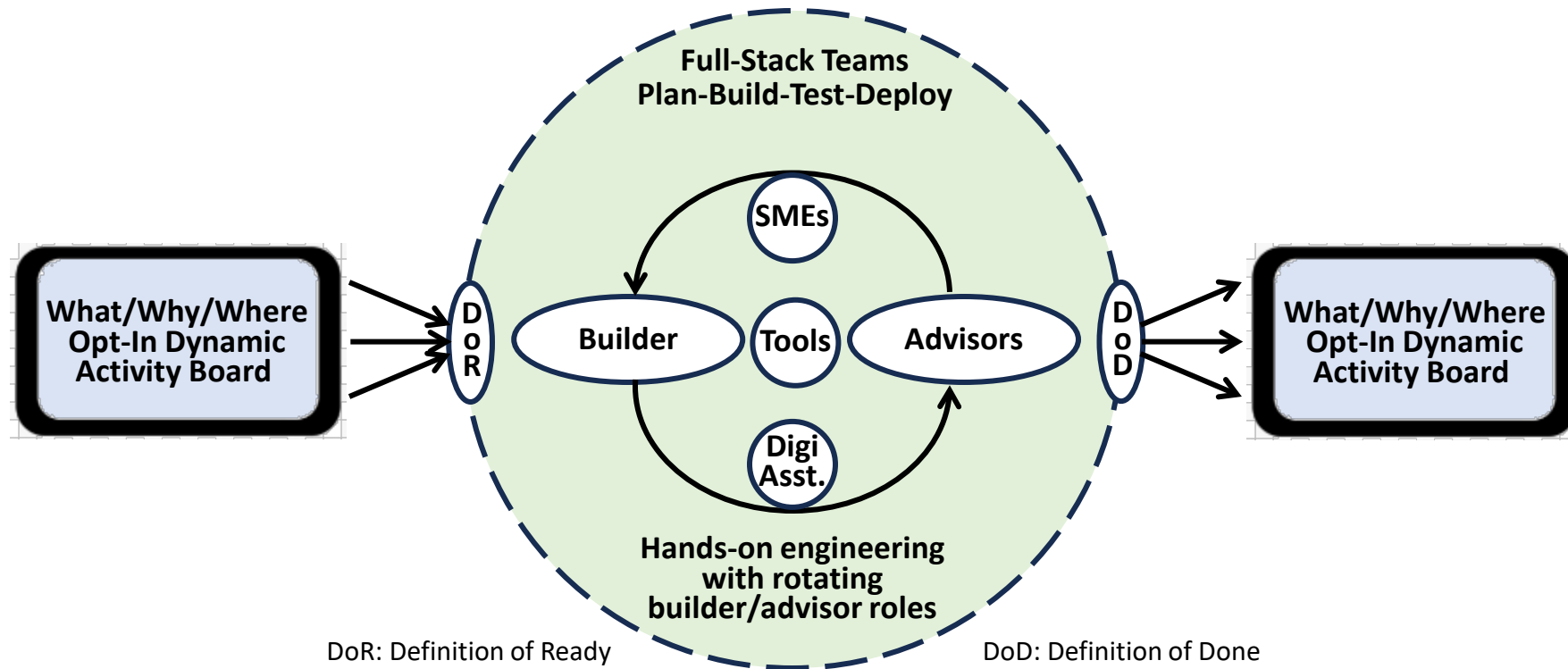www.weizenbaum-institut.de/media/Publikationen/Weizenbaum_Series/Weizenbaum_Series_31.pdf**

*"Pace of innovation is the only thing that matters –
not cost per unit, not management efficiency,
no other metric is above pace of innovation."*
Joe Justice. 2022. www.youtube.com/watch?v=ozdBx1SG-vo

**Tesla doesn't acknowledge an agile engineering strategy,
but their pursuit of continual engineering innovation
results in everything agile SE provides.**

Group Experiential Engineering
(simply a descriptive phrase, not a brand)

**Full-Stack Teams
Plan-Build-Test-Deploy**

SMEs

What/Why/Where
Opt-In Dynamic
Activity Board

DoR

Builder Tools Advisors

Digi
Asst.

DoD

What/Why/Where
Opt-In Dynamic
Activity Board

**Hands-on engineering
with rotating
builder/advisor roles**

DoR: Definition of Ready   DoD: Definition of Done

Build a little, test a little, learn a lot
(Rear Admiral Wayne E. Meyer, USN)

Engineering-Task Life Cycle Model

Opt-in Dynamic Activity Board.
- Anyone with a clear definition of mission can initiate a project.
- Missions are posted on factory displays and on personal-phone applications.
- Employees can opt-in to any team in need, independent of past experience.
- Engineers are expected to be capable of cross-functional mentored-learning on the fly.
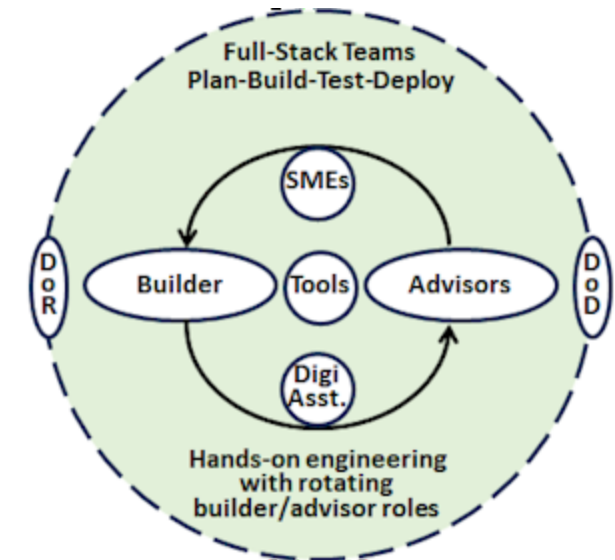
Full Stack Teams.
- Full stack means every necessary skill is present when needed.
- Engineering never pauses for missing skills.
- Teams can recruit within and outside when skills are scarce or needed.

Plan-Build-Test-Deploy.
A test-driven iterative sequence, where:
- Planning is a what-next collaboration, not up-front design.
- Building includes automating the manufacturing solution.
- Testing success has manufacturing and design documentation as an outcome.
- Deployment in-this-vehicle is a team and test decision.

DoR/DoD.
Definition of Ready and Definition of Done with straight-forward meanings well expressed by those phrases.
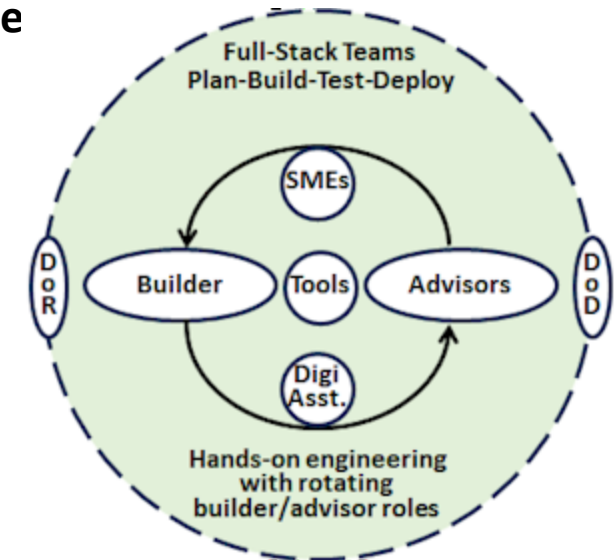
Hands-On Engineering

Tesla's culture features iterative experimental building rather than CAD or modeling up front.

Engineering is a hands-on experiential activity, not an arms-length intellectual activity.

Builders, Advisors, SMEs
- All team members routinely rotate out of one-person builder role into multi-person advisor roles.
- Less-experienced members have a steep cross-functional learning curve.
- Advisors may be fully engaged with a builder's activity, or providing support services.
- Group-flow is personally rewarding, highly productive, and collaboratively innovative

Digital Assistants
- Hundreds of AI/ML applications trained for testing and innovation evaluation:
  - Unit and integration regression testing.
  - Modular interface conformity.
  - Does it cost less?
  - Can it be assembled faster?
  - Does it perform its intended function better?
  - Does it have fewer lines of code?
  - Is it more visually appealing (*e.g.*, paint beauty evaluation data)?
- Other digital assistants help with supplier search, bidding, digital twin knowledge management, et al.

Natural Engineering – Not Procedural

The engineering process is a "natural-engineering" concept pattern at Tesla,
not a rule-based written corporate procedure.

For instance, rotation among builders and advisors does not always occur,
nor does a typical group size of 3-5 people preclude the occasional solo engineering activity.

And of course a new vehicle started from scratch doesn't begin
with welding a bunch of metal together hoping a Cybertruck will emerge.

"...people around the globe naturally form into improvisational groups.
The potential for creative collaboration is sitting there, waiting to be tapped.
Even school children can do it."   (Keith Sawyer. 2017. *Group Genius*, p. 44).

Group Experiential Engineering

xAI's Grok was asked: "What would group experiential engineering mean?"

"Group experiential engineering" isn't a widely established term, so let's break it down and reason through what it could mean based on its components.
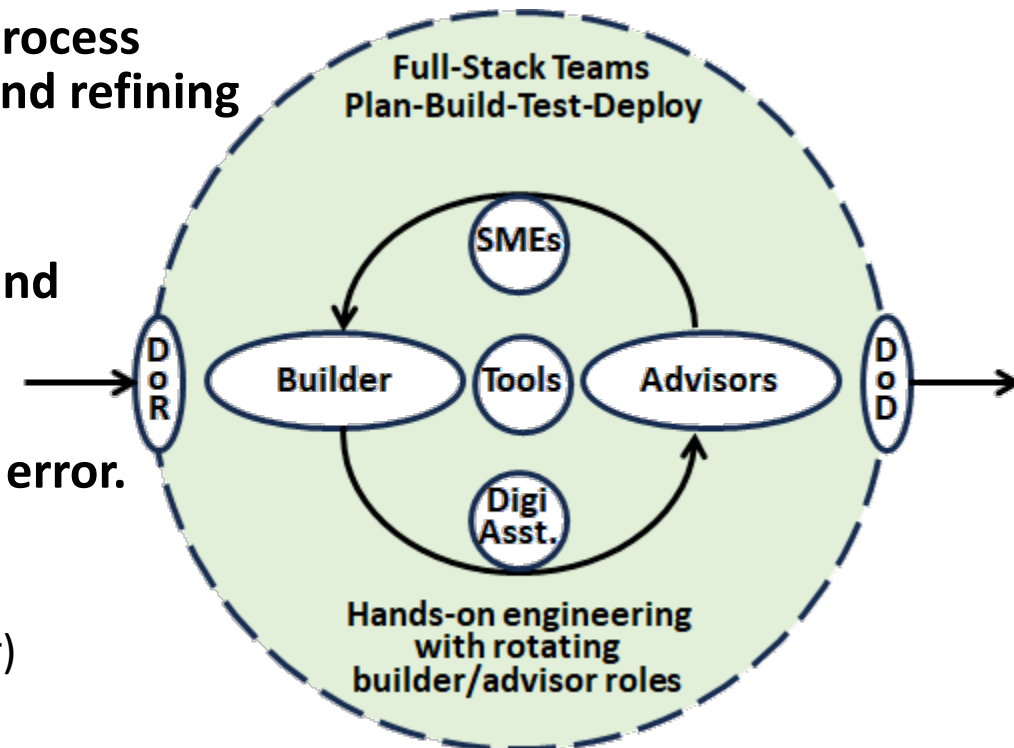
"Experiential" suggests something rooted in hands-on experience—learning or creating through doing rather than just theorizing. "Engineering" implies designing, building, or problem-solving with a practical outcome in mind. Add "group" into the mix, and it points to a collaborative effort, where multiple people contribute their skills, perspectives, or efforts toward a shared goal.

So, group experiential engineering could mean a collaborative process where a team designs and builds something tangible, learning and refining their approach through direct, hands-on experimentation.

Think of it as a bunch of people tinkering together—say, a team prototyping a robot, testing it in real-world conditions, and tweaking it on the fly based on what they observe.

It's less about following a strict blueprint and more about discovering what works through collective trial and error.
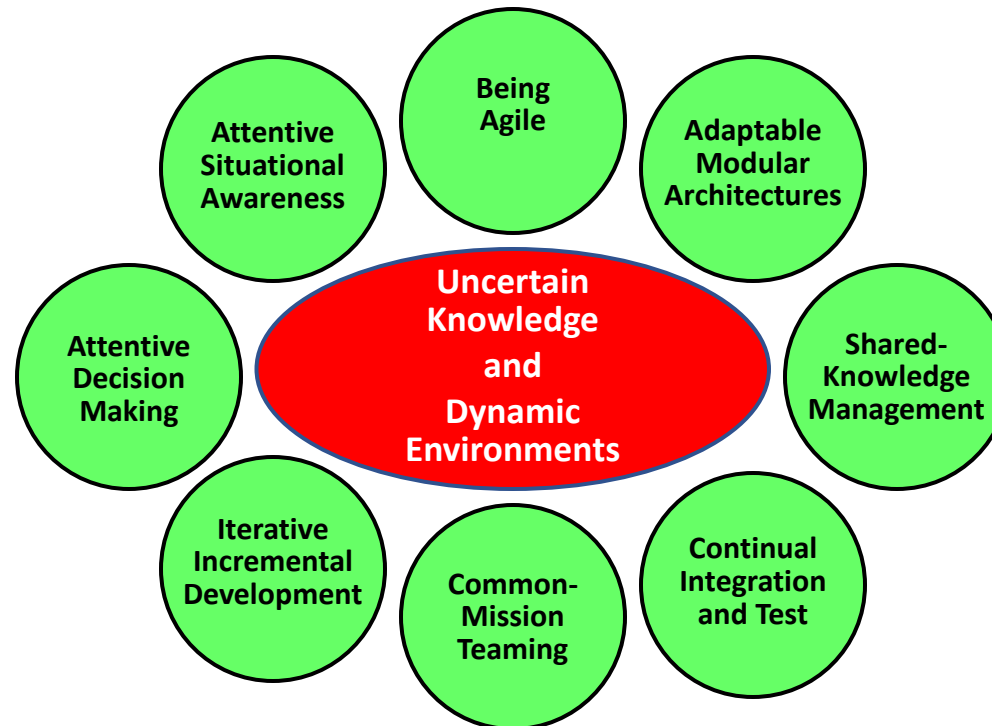
(all words above are a direct quote of Grok's answer)

Full-Stack Teams
Plan-Build-Test-Deploy

DoR — Builder — Tools — Advisors — DoD
SMEs
Digi Asst.

Hands-on engineering
with rotating
builder/advisor roles
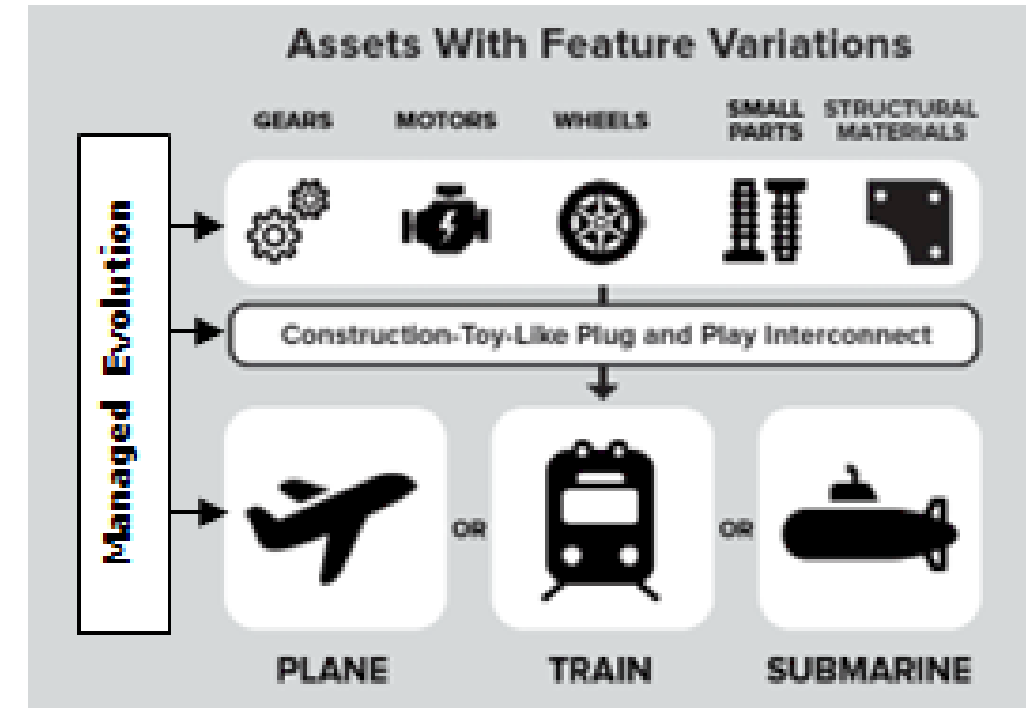
Eight SE Agility Aspects – INCOSE Primer

In practice at Tesla, these aspects are not overtly discernable as intentional separable strategies, but appear instead as a merged, overlapping, simultaneous way of working, a holistic cultural behavior.

Adaptable Modular Architectures

- **Modular architecture interconnect specs for everything: product, process, facility, production, tooling, and people.**

- **Opt-in modular teaming is enabled by infrastructure of culture and expected behavior in 3.5-page handbook.**

- **Strict architectural modularity enables multiple parallel engineering workstreams.**
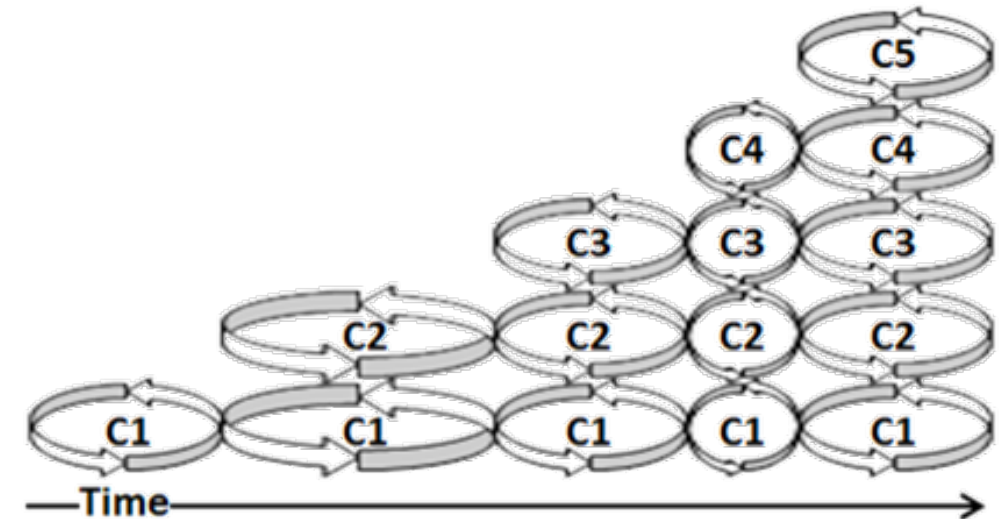

Composable reconfigurable constructions

Iterative Incremental Architectures

- **Every car has capabilities that can be improved at any time, and new capabilities that can be added at any time.**

- **Body sections that began as hundreds of welded & bolted parts transformed over time to become two castings.**

- **Every car drives itself through an in-factory certification test and registers that result with the NHTSA.**

Iterative capability improvements and incremental capability additions

Attentive Situational Awareness

- **Ubiquitous data-driven AI for continuous situational awareness at every factory station and in every vehicle.**

- **Group engineering motivated to innovate has many eyes, ears, and sensitivities.**

- **Vehicle usage by customers is monitored: how it is being used by people, how suitable it is for continued service.**

Air traffic control –
alert, in-the-moment, constant attention

Attentive Decision Making

- **Digital Self Management (DSM) AI app eliminates human manager decision delays by answering questions directly.**

- **Service options and scheduling are driven by operational monitors and digital twin profiles.**

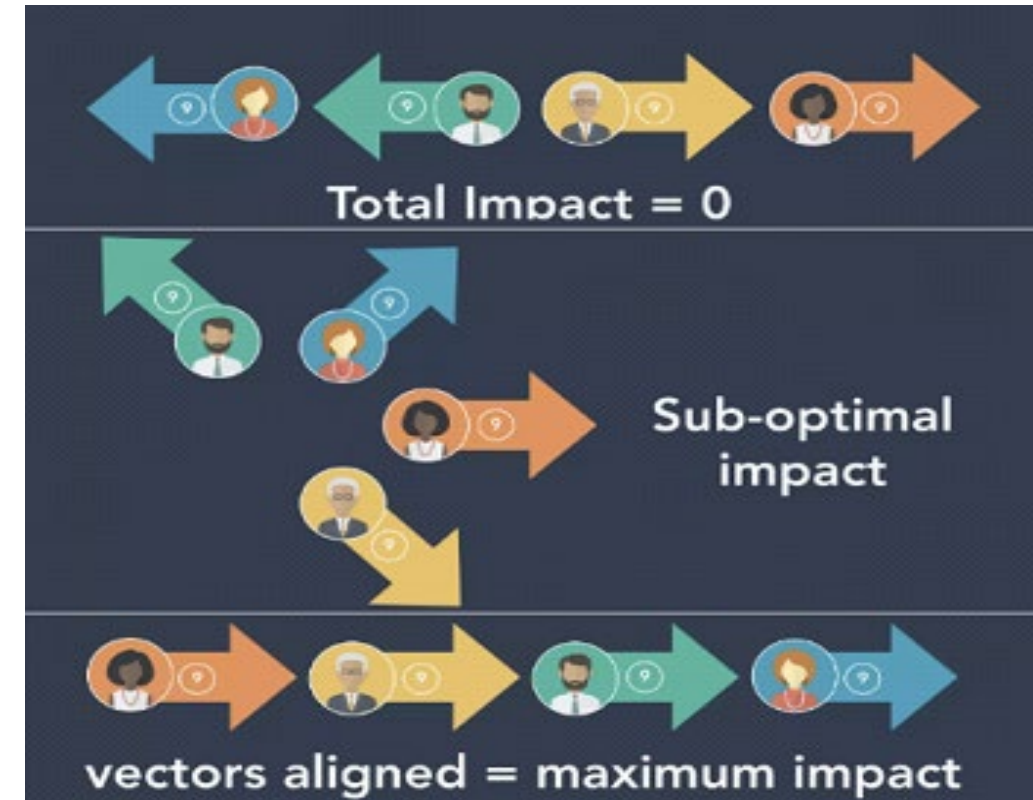- **AI provides data for immediate deployment decisions, no other authority is required.**

Attentive decisions change wrong tires that would take toll every lap

Common-Mission Teaming

- **Opt-in teaming is mission-pulled with postings on public boards and personal phones for mission resonance.**

- **Everyone works on the same thing at the same time in the same space, with rotating roles of builders and advisors.**

- **Team members police each other for staying on mission to avoid inefficient context switching.**

Team alignment determines total impact
(art: D. Shah, 2020)

Shared-Knowledge Management

- **Ubiquitous AI apps do long term knowledge curation and cross-facility dissemination.**

- **Work-in-process knowledge is continuously evolved on personal phones and factory screens.**

- **AI/DSM creates real-time feedback loop for skill and job improvement, and product and production improvement.**

Emraceable information containers of any kind, available to all, and typically digital

Continual Integration & Test

- **Every production line vehicle may have new parts, so all are treated as automated integration & test platforms.**

- **Production line vehicles run software doing integration regression testing as parts are added.**

- **Every car puts itself through automated testing of every non-destructive compliance and certification test.**
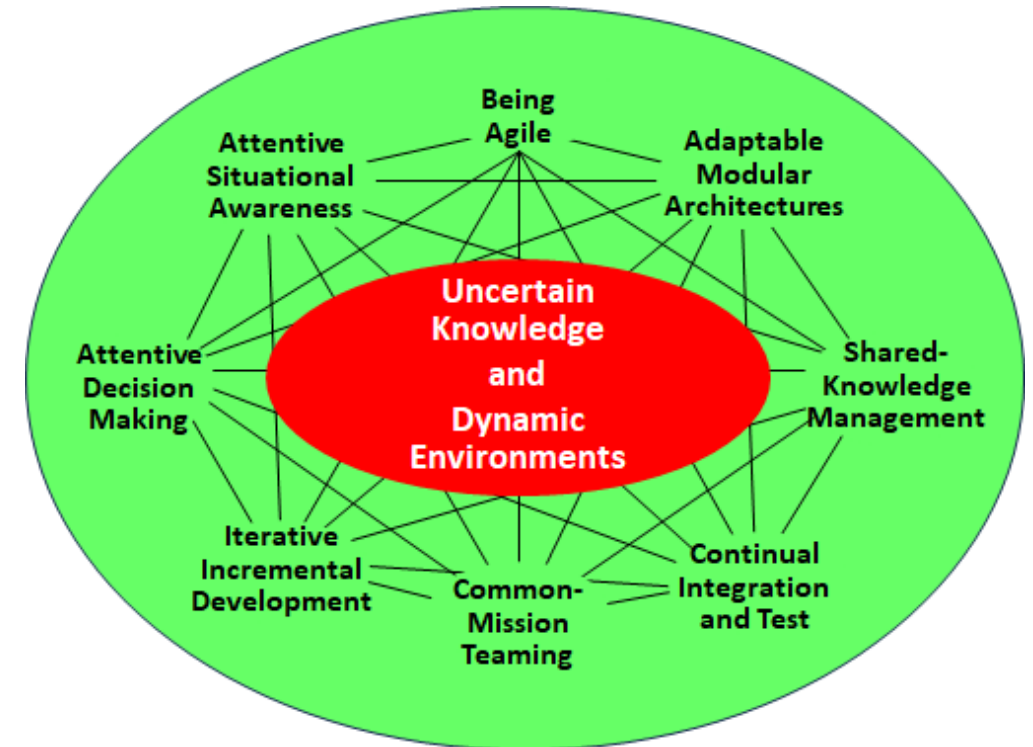

An iteratively evolving, self-driving technology, integration platform used at US Navy project
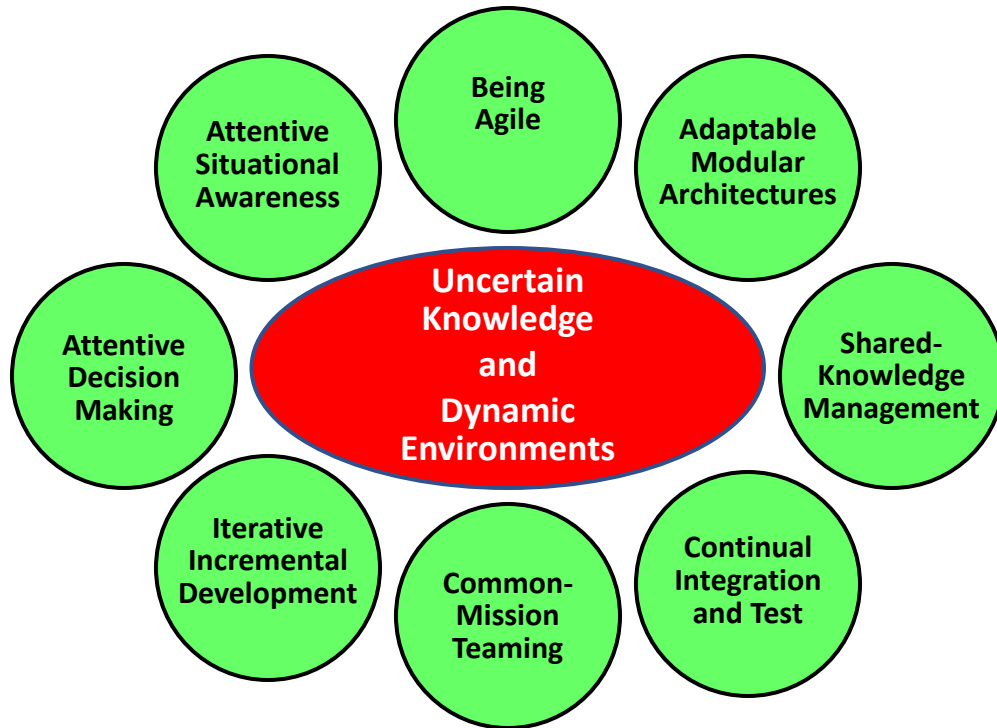
Being Agile

- **Agile engineering isn't recognized, but emerges from group experiential engineering for continual innovation.**

- **Sense-respond-evolve behavior with everyone passionately and compatibly engaged.**

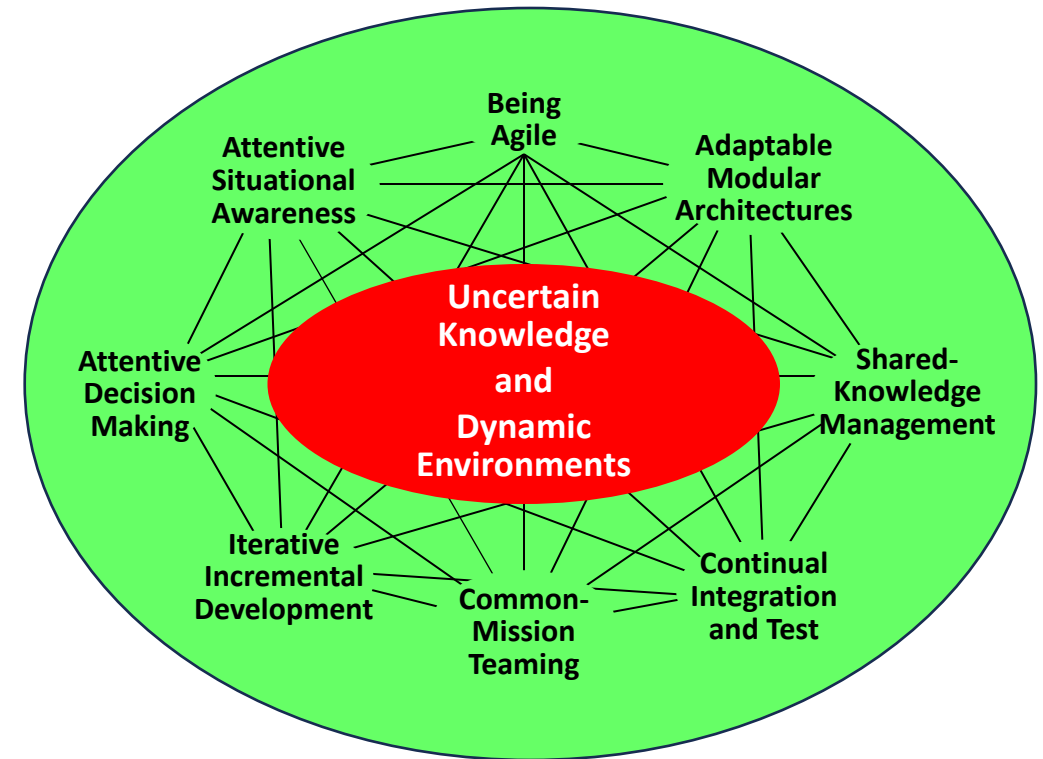- **Manifests as grace, efficiency, and effectiveness of situation-driven engagement.**

Agility emerges from sense-respond-evolve synergy among Aspects

Agility is an Emergent Behavior
of
Synergistic Aspect Relationships

Reductionist (Structural) View
Characterizes an aspect's nature in isolation
independent of its relationships.

Holistic (Behavioral) View
A network of synergistic aspect relationships
that manifest as holistic systemic behavior.

Starting From Scratch

New vehicle development doesn't begin with welding a bunch of metal together hoping a car will emerge.

Intended outcome for a vehicle might be conceived as:

- **a body style, e.g.,**
  - **pickup truck**
  - **stainless steel**
  - **home compatible**
  - **…**
- **a set of performance specs, e.g.,**
  - **power**
  - **range**
  - **safety**
  - **…**
- **a set of design guidelines, e.g.,**
  - **battery powered**
  - **modular architecture**
  - **software controlled**
  - **…**

This up front engineering takes months – and fits well with Group Experiential Engineering …
where "building" is iterative/incremental analysis and design done by grouped engineers.

Inspirations

These <u>concepts</u> can be applied in other environments, even contract development environments:

- **Opt-in teaming for critical bottlenecks and critical development will attract skills and passions that resonate with the mission. People driven by a sense of mission will produce faster and more innovative solutions than those who are assigned to a particular task or effort. Leverage criticality as a trigger for opt-in experimentation.**

- **Full stack group engineering for speed-critical engineering issues/opportunities, with everybody necessary and useful in the same room at the same time working together until the mission is completed. Again, critical need can be the trigger for a different approach where a faster solution is needed than would typically happen otherwise. Sensitivity to appropriate opportunities can spur experimental experience and refine employment experience.**

- **Automated regression testing of incrementally-integrated work in process.**

- **Rapid data-driven decision making enabled by digital curation, association, transparency, and availability.**

- **Modular architecture and interconnect standards that enable interference-free parallel workstreams and capability improvements.**

- **Product engineers and production engineers working together simultaneously with a merged work stream – iteratively designing (or improving) and building a system/subsystem/component/part and how to produce it. Learning opportunities with payback might be parts that are difficult or costly to produce.**

- **Management automation – not wholesale, but incremental identification of what waits for approvals and decisions that could be automated, with priority on low hanging fruit and high-pain delays.**

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