Factory Delivery Use Case

Industrial Internet Technology Working Group

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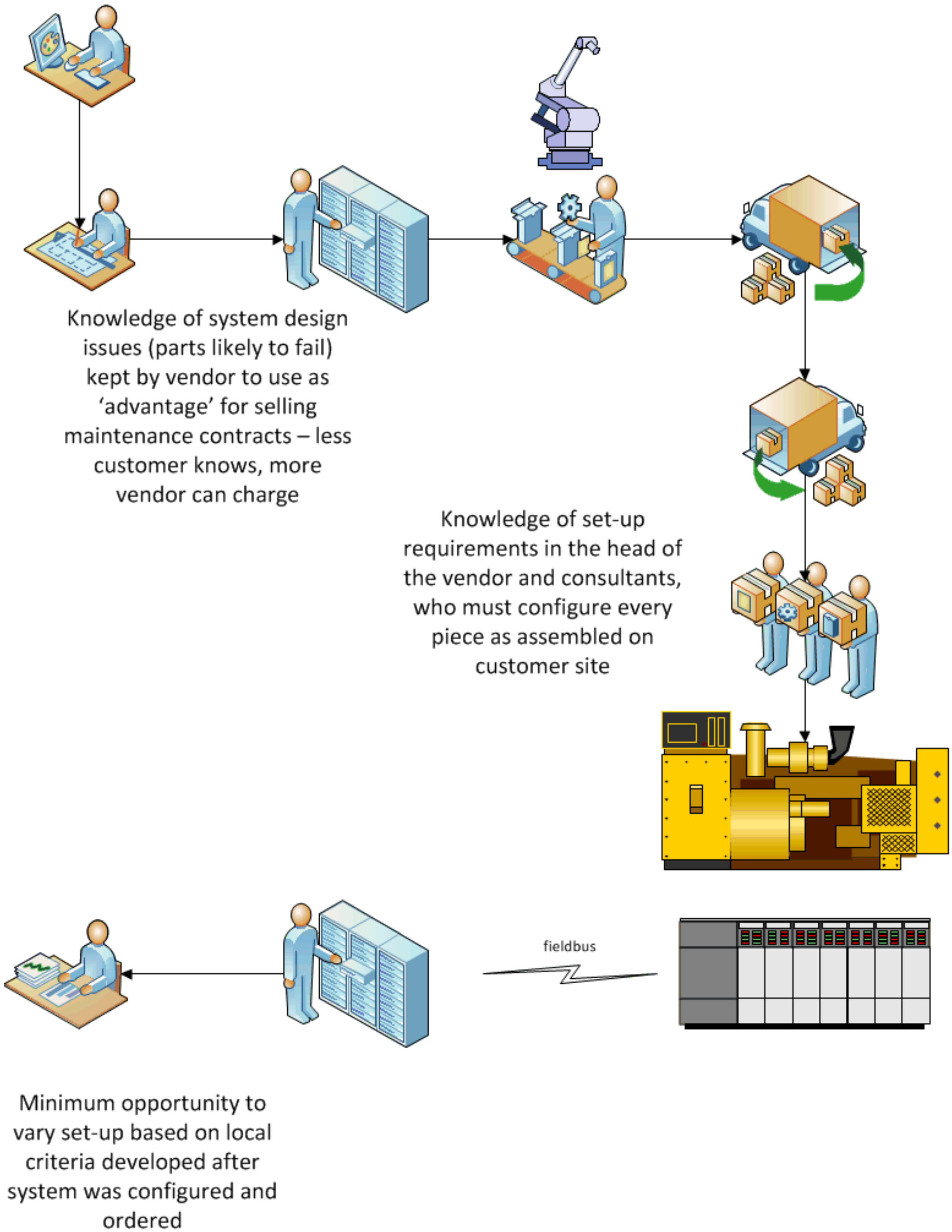
The following is motivated by a 'factory field service' use case (that is, sending a field service technician to a factory to repair a machine). However, since the factory of the future is itself different from the factory of today, two examples are given, the 'as-is' case to set a baseline, and the 'to-be' case as what I believe represents the kind of issues we will have in the factory during the lifetime of the industrial internet. The idea is to motivate the significant problems as we move from dozens of network enabled devices to millions (per deployment), while minimizing the manual effort otherwise required if we continue to 'do things the way we have been.' I emphasize the effort of modeling (understanding how the equipment should behave), currently only in the minds of the engineers who design the factory, and configuration (setting up the equipment with the correct behavior and ability to interoperate) currently performed by, e.g. IT personnel and controls engineers.

1. As-Is - Initial Factory Delivery

Technology/Field Service/UC001: Initial factory delivery AS-IS	
Vignette	Months are spent with vendors and consultants deciding on everything based on what is to be produced, with the company providing their own experts in manufacturing to specify how the line will be laid out, the product to be produced, and the method of manufacture. Over many months, the factory is slowly built, with machines delivered, tested, and occasionally broken down and reconstructed. Changes are made as the newest machines delivered late prove to be incompatible with the machines delivered early. As the process stretches on, more changes are made due to changes in the product design. Finally the factory is ready and a large crew of operators and workers take over. Training commences on the actual machines delivered and the vendors spend weeks showing the ins and outs of the various devices and their safety features. Finally the factory is switched over to low unit production to iron out the remaining kinks and assure that the line will be operated to the company's policies.
Actor	Vendors, consultants, company representatives, cast of thousands
Event	Decision is made for new factory
Pre-/Post-Conditions	Pre: Company owner makes sure they have enough cash, and that shareholders will react favorably to the news Post: Factory engaged in low unit production

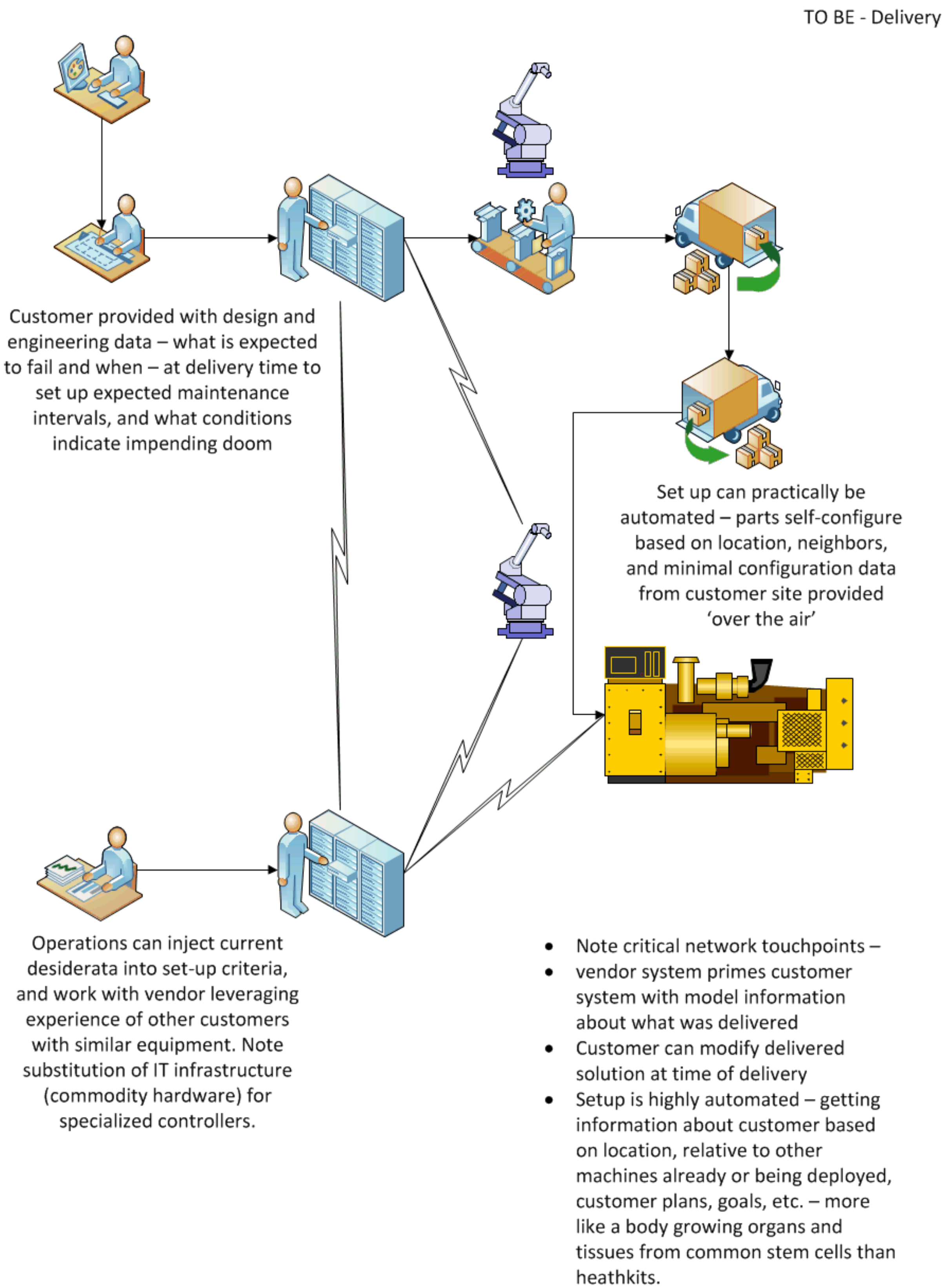
AS IS - Delivery



Technology	We have it, today
Fit Criteria	We're in it, together
Scenario	Design and development of product carried on by OEM. Engineering trade-offs that are made on lifing (the expected service life of parts) and normal operational ranges for the product line and models are documented in a way that they are available to field service personnel. A subset of this is also made available pre and post sales to the customer, primarily to differentiate the product in the customer's mind from others, and to allow for safe operations. Specific model configuration and deployment is typically performed by the OEM or a consultant/vendor using expertise provided by the OEM. NRE is charged to the customer to configure to their specific deployment and operational needs. Generally speaking, while this information is used to make appropriate selections from the product line, no specialized data on expected performance of the instance is made outside of the generic information on the models selected. (Example: you buy the 18" wheel option on your Accord based on general knowledge of what the difference between 17" and 18" wheels are, but you don't have access and nobody actually calculated, the change in wear on the brakes, the engine, the traction, etc. on the specific car you will buy with that particular engine, tire, etc.) There are enough sensors in the machine to allow for operations staff to perform supervisory control leveraging a SCADA system. During deployment, rules that tie together the specific sensor (addresses), where things were plugged in, etc. are modified and developed for the specific customer task by consultants and control engineers. These sensors are sufficient to maintain the system in control, but generally are not sufficient for condition-based maintenance (measuring detailed information about all parts of the system over time to compare to performance curves of similar system to determine where they are in the model's life profile allowing one to better predict when failures and maintenance actions may occur). After deployment, system is monitored by in-house staff, using limits presented to them by the installation vendors, with general knowledge about what normal operations should "look like" on the UI, and how to detect likely failures or make extraordinary control actions (such as manual overrides to prevent an overheat).

Notes	The glide path here is toward condition based maintenance, which will involve more sensors and more data collection. Additionally, because operational expertise is not always available on-site (economically or technically), remote monitoring and operations are desired and that is where the market appears to be moving (my opinion). However, the conflict is that as more data is generated and collected, it becomes harder to perform sensemaking by the kinds of operators that have been traditionally hired, accelerating the trend toward remote operations where more skilled personnel manage larger numbers of systems. The networking issue here then (in the evolutionary scheme) is for larger bandwidth communications with limited latency allowing such remote operation of plants that typically have 10Hz updates to the supervisory interface (and may be 100-1000Hz on the local loop).

2. To-Be Initial Factory Delivery



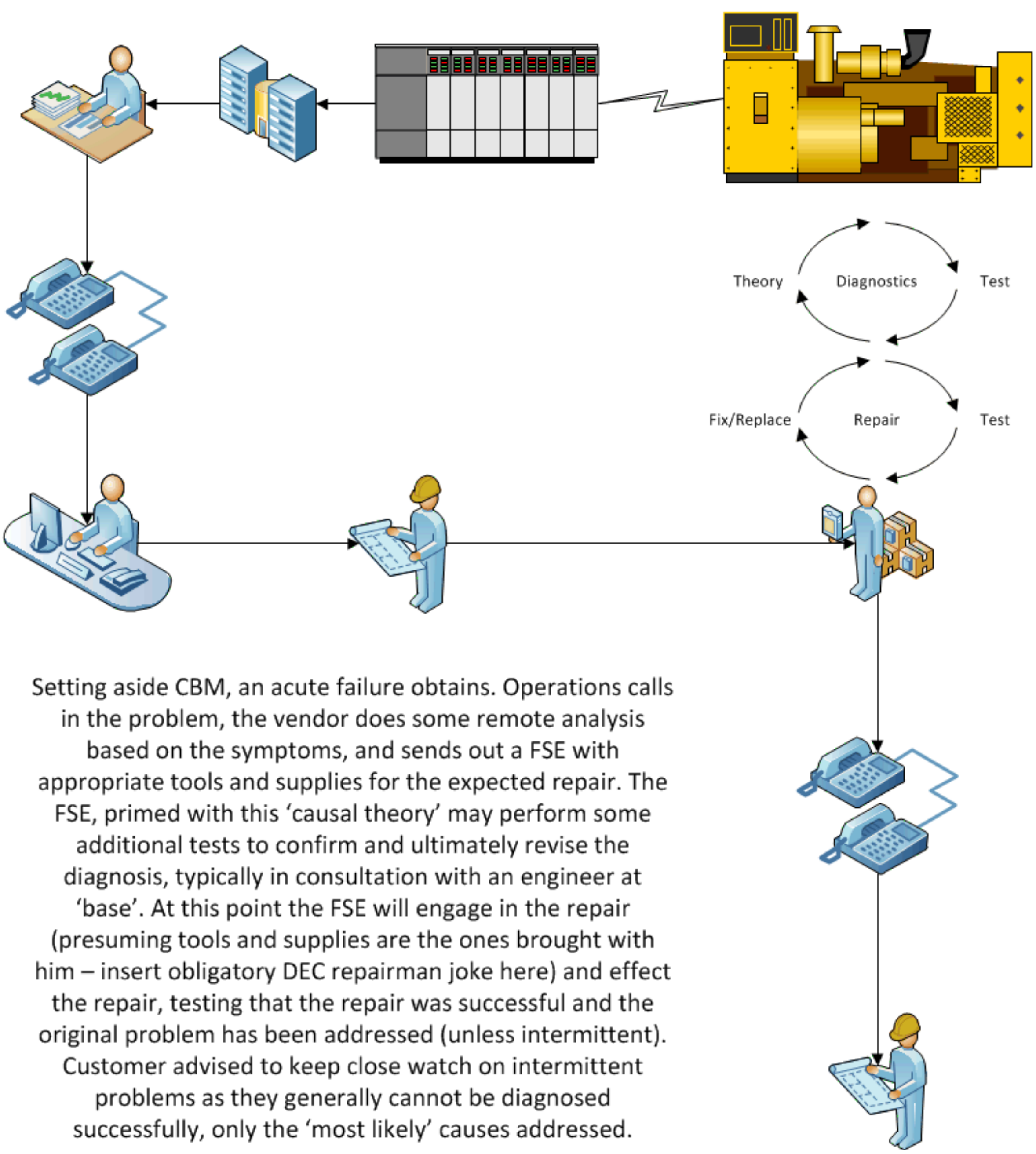
Technology/Field Service/UC001: Initial factory delivery TO-BE	
Vignette	Order placed based on size of installation and general idea of product rather than specific siting, NRE required, etc. After some hours, local ISP shows up with network termination panel for the site. Delivery of in days (rather than years) of small cubic blocks of apparently identical material which is unloaded by robots that appear to be constructed of the same material. A connection is made to the network termination panel for a device that provides wireless access. As we watch, the cubes begin to form machines, conveyers, and more robots. The delivery robots join the team constructing the factory. After several hours, operations begin.
Actor	Company VP, ISP Technician, Piles of robots
Event	Decision is made for new factory
Pre-/Post-Conditions	Pre: Company owner makes sure they have enough cash, and that shareholders will react favorably to the news Post: Factory engaged in low unit production
Technology	Organic / amorphous computing self-reconfiguring modular robots mechanisms for addressing, discovery, location awareness, context awareness, self-*
Fit Criteria	Profit!
Scenario	

Notes	Given the trend toward individual smart sensors and actuators, deployment in the future will be less about selecting a particular model that has already established a set of operational parameters and trades made, and more an overarching framework in which tens of thousands of individual networked subsystems are interconnected in a way that achieves the customer needs. As the number of interconnected systems scales up, one challenge will be that the number of personnel needed to set up the system must also escalate, increasing costs and coordination efforts. We therefore suppose that automation must substitute for increased vendor effort on deployment, ultimately providing automated deployment – perhaps on the amorphous systems model (all components are interchangeable modules, that, similar to stem cells developing into specialized cells during gestation, use contextual cues to determine what their 'role' in the developing and completed system actually is). One implication is that the information about the desired deployment is no longer carried in the heads of the vendors, but must be generated from information provided by the OEM and the customer – establishing the "DNA" so to speak for the differentiation process to begin. And the networking needs that were nonexistent during deployment (until initial startup) in a traditional approach are now critical during set up, as elements must be able to determine their owner, their (physical) neighbor, their neighborhood, their deployment goal, etc. In addition the design information previously held by the OEM as a "service advantage" needs to be distributed into the network to allow such self-configuration including the information needed by operators to notice the system is within limits (though the system itself will notice and presumably adapt to any out-of-limits condition long before an operator would notice). Services "in the network" that provide autonomic configuration and healing capabilities must be primed with specific information about the part instances used (in addition to generic information about the model) in order to establish their own automated strategies for corrective control. Think about this as the difference between how one builds a house where a defective (twisted) 2x4 has been delivered. In the as-is case, we call the vendor and return the defective 2x4 or throw it away. In the to-be case, we change the rest of the house so that the twisted 2x4 becomes the perfect fit for a dramatic entranceway with similarly twisted doors and windows. C'est très avant-garde! And because that twisted 2x4 is really an amorphous device, it can change it's twist, perhaps in time to music, along with the rest of the house. And you thought those bouncing **cars** were cool [well, maybe not].

More Notes	But this means that in addition to operational data that's flowing across all these network connections, there are also configuration data (because who says the configuration has to be static anymore?). And because the processing of that data is no longer necessarily local (well, we presumably filter and compress and toss the irrelevant stuff locally turning the data into information in some semantic language that captures context-free representations of dynamic state, with some ability to use pragmatics to capture context) in order to send highly compressed language streams to remote sites for operation, configuration, and prediction. [Think about the early use-case for human language development — to improve hunting!] Unfortunately, due to the large numbers of machines that are interconnected, there is now a timing problem – we have to make sure that the data is synchronized so when we are interpreting the latency of sensor A and sensor B which require different amounts of internal processing, we understand that the underlying phenomena that is being described is from different 'snapshots' if we only compare what the devices output at the same time. Thus distributed time-base and time-stamping of observations and actuations (since actuation would have similar issues) could be critical – and support better prediction as we will be able to notice what phenomena are actually simultaneous or nearly so (and therefore admissible to a causal model). It is not clear that such synchronization need be global however; local synchronization allowing *emergent control* may be sufficient. [Kreyssig, Peter & Dittrich, Peter "Emergent Control" C. Muller-Schloer et al. (eds.), *Organic Computing – A Paradigm Shift for Complex Systems,* 67-78. 2011 Springer (Birkhauser)]

3. As-Is Acute Sudden Failure

AS IS – Acute Sudden Failure

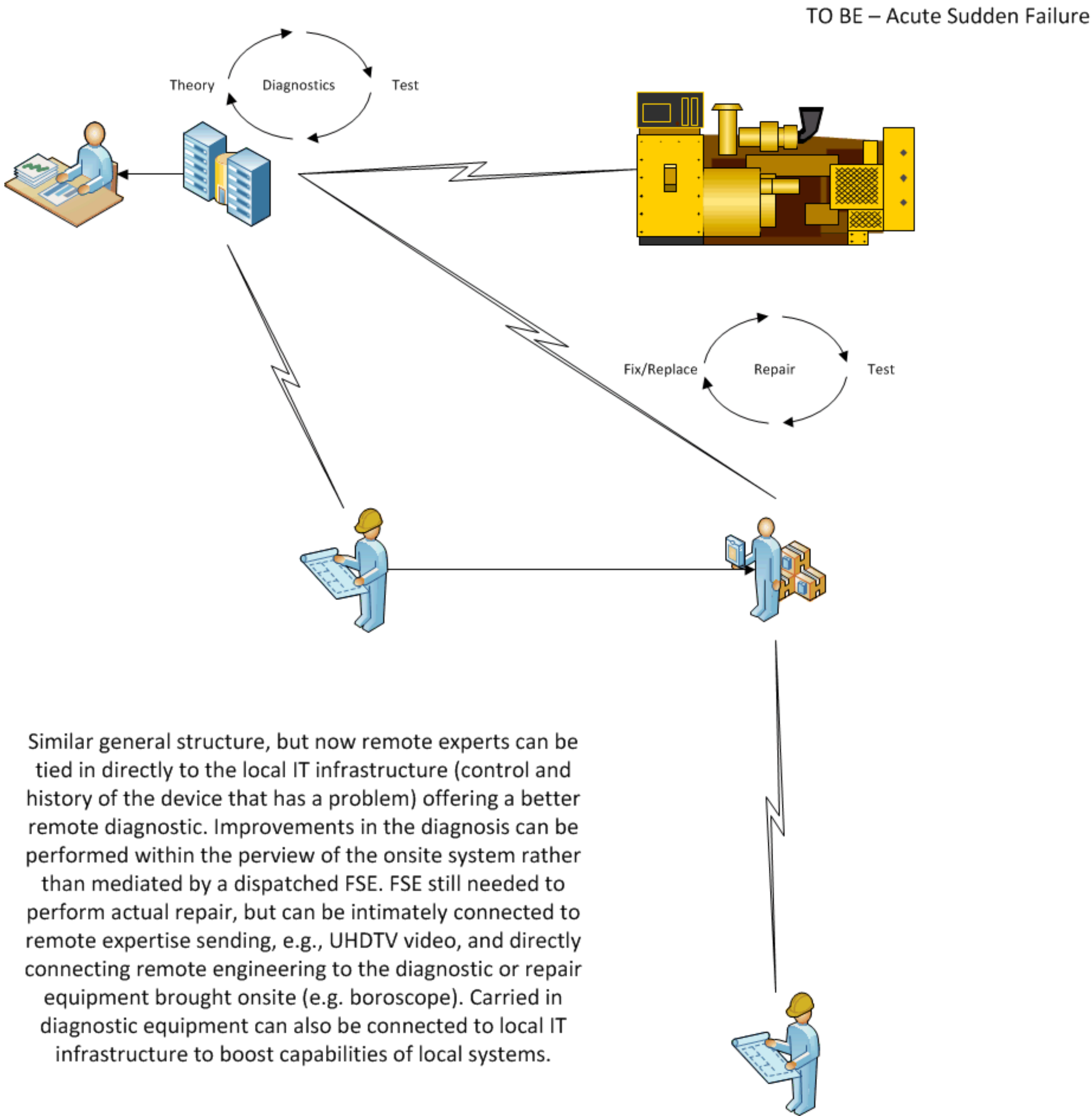


Setting aside CBM, an acute failure obtains. Operations calls in the problem, the vendor does some remote analysis based on the symptoms, and sends out a FSE with appropriate tools and supplies for the expected repair. The FSE, primed with this 'causal theory' may perform some additional tests to confirm and ultimately revise the diagnosis, typically in consultation with an engineer at 'base'. At this point the FSE will engage in the repair (presuming tools and supplies are the ones brought with him – insert obligatory DEC repairman joke here) and effect the repair, testing that the repair was successful and the original problem has been addressed (unless intermittent). Customer advised to keep close watch on intermittent problems as they generally cannot be diagnosed successfully, only the 'most likely' causes addressed.

Technology/Field Service/UC001: Acute Sudden Failure AS-IS	
Vignette	*After a failure is noted by an operator (smoke, lots of alarms, buzzers, bells, general pandemonium followed by silence if lucky), a phone call is made to the service operation, symptoms are input and dispatch of an FSE with estimated needed equipment for the class of failure is performed. 4-48 hours later (depending on the service contract), FSE arrives on site. Initial theory based on some features of failure start the diagnostic efforts, and telephone based collaboration with shared experts (at one or more home sites) narrow in on discovering the problem. The FSE is usually an active member of the diagnostic team, and can perform simple diagnoses themself (looks like the fuse shorted causing the panel to catch fire). After some amount of interaction, a repair is performed and then tested to assure that the problem does not immediately recur and that all functions are now nominal.*
Actor	Operator, FSE, Experts, all human
Event	Sudden Acute Failure (unpredicted)
Pre-/Post-Conditions	Pre: Everything running just fine Maintenance contract paid up I didn't push that button, honest! Post: Everything working again Did you really think we wouldn't know you pushed the button Malicious intent is not covered under your maintenance agreement
Technology	Fuses that cause more damage (like on Star Trek)
Fit Criteria	It's all working again 9 5's reliability. It works, 55.5555555% of the time.
Scenario	

Notes	Perhaps the largest evolution currently happening is the movement toward condition-based maintenance, already mentioned, which should predict most failures before they occur. The requirement is for large amounts of sensor data to be comparable to identical systems whose performance envelope over time is known. It does not work as well when systems are typically unique as the ability to transfer knowledge obtained from other systems is hampered primarily due to overtraining, however knowing what data is important and what isn't is still an open problem. Many of the lay II examples are essentially that – lots of sensors, send the data to a central site, perform analytics, decide what needs fixed or what control parameters need adjusted based on lifing. The argument that this is "big data" – but real "big data" problems involve so much data that the data cannot be moved! Bringing us to…

4. To-Be Acute Sudden Failure



Technology/Field Service/UC001: Acute Sudden Failure TO-BE	
Vignette	*After the local system detects a failure, automated diagnostics and tests are engaged, and remote expertise are immediately notified and brought into the diagnostic cycle without waiting for a FSE. Real-time synchronized sensor information is presented across multiple systems for remote diagnostics, including 8K video feeds, allowing remote systems to perform emulated control under the direction of local and remote algorithms as well as remote engineering teams. A FSE is dispatched if necessary with the tools and materials needed to perform a repair, but unless the diagnostic system is itself compromised, will usually not be needed for on-site diagnostics, however, can carry in advanced tools (e.g., X-Ray) if needed for specialized work. FSE may also carry a 3-D printer in their truck to synthesize additional parts for repair rather than having to return for additional inventory if the initial diagnosis proves insufficient. FSE is generally not a participant in the diagnostic process, rather a set of hands (which could be mostly automated with on-site robotics given the right service contract). Because of the interactive nature of the diagnosis can be continuous with system operation, there are constant opportunities for system improvement and optimization with improved parts, learning more about* ***this particular system*** *over time, rather than relying on similarities to other identical systems.*
Actor	local system, remote expertise (may be artificial), FSE (may be robotic)
Event	Failure detected by local system *HAL*: I've just picked up a fault in the AE35 unit. It's going to go 100% failure in 72 hours.
Pre-/Post-Conditions	Pre: HAL sane Post: We've improved the system.
Technology	
Fit Criteria	
Scenario	
Notes	The last point implies sufficient dedicated computational resources to be continuously performing learning (such as stochastic gradient ascent – shown to be similar to human learning performance in that small amounts of data can be leveraged though other processes are necessary to focus attention on likely causal relationships – simultaneity seems to be a key predictor).