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Tractors—At the Intersection of Digital Technology and Culture

Rapid advances in technology and especially the development of products with embedded computer systems have had a growing and in certain cases an adverse impact on users and grassroots innovation, particularly since the enactment of a federal statute in 1998 originally intended principally to protect copyrights of movies and music but which has had a pronounced effect on a wide range of other products such as automobiles, tractors, phones, appliances, and other products with embedded digital technology.

Agricultural equipment, more specifically tractors and other farming machinery, offers a compelling case study of what has been happening in the rural economy and to users of these products and its impact on innovation and consumers right to repair such products. Tractors, which often are viewed as relatively simple, mechanical devices are now increasingly dependent on digital systems. Tractors are the workhorses of the modern farm and are used by both large commercial and small subsistence farms for a large variety of tasks from plowing to hauling and planting.

Under the 1998 copyright law, farmers have not been able to modify their tractors to better suit their needs and the types of tasks they want to accomplish as the newer agricultural equipment is increasingly dependent on digital monitoring systems which contain copyrighted

content. The Congressional Research Service reports that “[t]he Digital Millennium Copyright Act (DMCA) generally forbids anyone from disabling “technological protection measures” (TPM) (such as passwords, codes, and encryption) that exist in consumer products to prevent the unauthorized duplication or distribution of copyrighted materials contained in those products (such as music, movies, and software).”¹ “The DMCA also subjects individuals and businesses to civil and criminal penalties for engaging in unlawful acts that ‘circumvent’ TPM.”²

Perversely, a law designed to protect the fruits of innovation, certainly in the entertainment industries, had had collateral effects on consumers over a wide range of industries including agriculture where innovation of tractors and other farm machinery has long been important its success and growth. At the end of the 19th century, steam-powered tractors, an outgrowth of technological innovations combined with analog devices, entered the agricultural stage, replacing the horse- and oxen-drawn plows and leading to the expansion of farm acreage.³ By the 1920s, a new innovation in farm equipment, the gasoline-powered tractor, occurred and became prevalent as its smaller size made it more versatile than its steam-powered predecessor.⁴ Over the decades, modifications were made by the tractors’ owners to make them more powerful and fuel-efficient. By 1954, the number of tractors on U.S. farms, for the first time in history, surpassed the number of horses and mules.⁵ As of October 2015, almost 180,000 tractors and

¹ U.S. Library of Congress, Congressional Research Service, *Copyright Law Restrictions on a Consumer’s Right to Repair Cars and Tractors*, (2015).

² Ibid.

³ National Agricultural Statistics Service, “About NASS,” *United States Department of Agriculture* (2005): 5.

⁴ Ibid., 9.

⁵ National Agricultural Statistics Service, “About NASS,” *United States Department of Agriculture* (2005): 12.

5,000 combines had been sold in the U.S. agricultural sector with the majority of the sales being John Deere products.⁶

Agricultural machines without computer systems could be repaired and modified by farmers themselves. However, the latest innovation in agricultural equipment has been the addition of electronic computer units (ECUs), which are responsible for monitoring the equipment's functionality and recording information regarding any part failures or system malfunctions.⁷ This information is encrypted by the manufacturer and fall within the DMCA. As a consequence, "Several groups have asked the [Copyright Office, the organization in charge of granting exemptions to the DMCA,] to recognize an exemption that permits the consumer to circumvent TPMs on software programs that control the functioning of motorized land vehicles and agricultural machinery, in order to perform diagnosis, repair, personalization, modifications, or other improvements to the vehicles. If consumers try to conduct those activities by themselves, they may be violating copyright law if the work involves tampering with any digital locks protecting the software that controls the engine, braking, steering, entertainment system, and other mechanical functions."⁸ In response, the foremost manufacturer of tractors, John Deere, "has opposed the proposed exemption, arguing that circumvention of TPMs 'will make it possible for pirates, third-party software developers, and less innovative competitors to free-ride

⁶ Association of Equipment Manufacturers, October 2015 Flash Report: United States Unit Retail Sales, November 10, 2015.

⁷ *Petition for Proposed Exemption Under 17 U.S.C. § 1201*, USC Intellectual Property & Technology Law Clinic, 2015, regarding agricultural machinery.

⁸ U.S. Library of Congress, Congressional Research Service, *Copyright Law Restrictions on a Consumer's Right to Repair Cars and Tractors*, (2015).

off the creativity, unique expression and ingenuity of vehicle software designed by leading vehicle manufacturers and their suppliers.’’⁹

The issue is particularly acute for the small-scale farmers, who tend not to have multiple tractors and may lack the resources to outsource repairs to dealers authorized by the manufacturer and endure the delays in having the equipment return to operation. Small-scale farmers have always been more than just food producers. They are problem-solvers and mechanics as well and traditionally tractors have been modified and repaired by their farmer owners to better suit their needs and perform tasks more efficiently without the need for outsourcing their repair or modification. Even the genesis myth of John Deere spins a tale of innovation and problem-solving.

The role of the designer in this situation has several dimensions. Firstly, a designer can serve as a strategist and investigate the pathways for change in order to identify points for intervention and crafting solutions that improve existing and future conditions. In the case of wicked problems that involve multiple systems and stakeholder groups, the problem must be thoroughly examined, requiring an assessment of the problem’s impact on the society as a whole. By looking at the problem in terms of the economic, technological, and environmental spheres, (the infrastructure), the policy-making and legal spheres (the structure), and the cultural trends and ideologies (the superstructure), the various motivations and interests of the key players can

⁹ U.S. Library of Congress, Congressional Research Service, *Copyright Law Restrictions on a Consumer’s Right to Repair Cars and Tractors*, (2015).

be more readily seen.¹⁰ Mappings of the various complex relationships can lead to a better understanding of the interaction among these elements and a socially acceptable solution (Figure 2).

In the case of agricultural equipment and copyright law, mapping the problem reveals the severity of the issue at hand. Tractors are artifacts of the infrastructure, the only component of a culture that has the power to affect significant societal change or cause a cultural shift.¹¹ Currently, policy-making through laws and regulations, a function of the structure, is limiting the ability of these infrastructural tools to be modified by the user. The freedom of users of these products to adapt to changing environmental and economic conditions is crucial in agriculture as stagnation of innovation at the infrastructural level has the potential to stagnate growth and affect the stability of the structure and superstructure. It is the strategic role of the designer to locate these choke points in the system and design solutions that eliminate the social and economic tensions while considering future conditions.

Farmers who depend on tractors for their household economy and advocacy groups concerned with the impact of this choke point on agriculture are seeking solutions along two pathways. One path is to find ways to work around the DMCA by creating open source farm equipment not subject to DMCA, often reminiscent of primitive tractors and plows, that are

¹⁰ The concepts of infrastructure, structure, and superstructure are borrowed from social science research, particularly anthropology, and have analytical power in this setting. (Figure 1)

¹¹ Changes at the infrastructural level ripple upwards, affecting change to the structure and superstructure. While there is some feedback from the superstructure, it is relatively insignificant and will likely not lead to cultural shifts (Figure 3)

cheap and easy for small-scale farmers to manufacture on their own.¹² Inventions, such as the culticycle, a pedal-powered tractor constructed from bicycle and lawnmower parts, fulfills the role of the tractor and can be built using open source plans and instructions found online (Figure 1).¹³ Others, seeing limitations of the newer model tractors, have responded by returning solely to older models that do not use protected technologies.

A second path is to work with the existing systems and circumvent its restrictions, entering a grey area in terms of compliance with copyright law as currently in effect. Generally, those seeking to modify or repair a tractor must work around the barriers embedded in the ECU. Manufacturers restrict access to these onboard computers by “programming them to only respond to proprietary [manufacturer] software.”¹⁴ Furthermore, in order to access to the embedded software, the ECUs require both a computer with the proprietary software and a cable designed to connect to the proprietary data ports of the ECU.¹⁵ The propriety software communicates with the embedded software via “a virtual ‘handshake,’” so even if one has the right cable, without the manufacturer’s software, access is still restricted by the propriety design of the data ports.¹⁶ In general, the manufacturer only supplies this software to authorized dealer technicians. While versions of the software with limited-functionality are sometimes provided to

¹² Farm Hack, “Getting Started,” Accessed November 12, 2015, www.farmhack.org/wiki/getting-started.

¹³ Farm Hack, “culticycle,” Accessed December 10, 2015, <http://farmhack.org/tools/culticycle>.

¹⁴ *Petition for Proposed Exemption Under 17 U.S.C. § 1201*. USC Intellectual Property & Technology Law Clinic. (2015): 6.

¹⁵ Ibid.

¹⁶ Ibid.

third-party service centers and mechanics, rarely are they given to individual farmers upon purchase of a new tractor.¹⁷

Acquiring the manufacturer's software can be a difficult and expensive task and subject the tractor owners to legal risk. Options include: purchasing the software from someone who has it, paying someone who has developed their own, finding people who are willing to share, or developing their own compatible software.¹⁸ The demand created by these circumvention tactics has created a niche market for compatible software, development of which is occurring mainly outside of the United States.¹⁹

Even with the compatible software, access to the ECUs requires TPM hacking to access important information and settings protected by both "factory passwords" and "consumer passwords".²⁰ Manufacturers use the "factory passwords" to prevent farmers from accessing diagnostic tools and engine performance settings, "programming a new ECU (necessary for replacing malfunctioning ECUs)," acquiring "consumer passwords" that allow for reconfiguring important parameters, and clearing fault codes that can prevent the proper function of the tractor.²¹

¹⁷ *Petition for Proposed Exemption Under 17 U.S.C. § 1201*. USC Intellectual Property & Technology Law Clinic. (2015): 6.

¹⁸ Ibid.

¹⁹ Ibid.

²⁰ Ibid., 7.

²¹ Ibid.

Once again, farmers have found multiple ways of circumventing these barriers, including getting the passwords from other farmers or mechanics, searching online for ones that have been shared, hacking the password manually, or using devices “that attempt thousands of guess attempts per second until the correct password is discovered.”²² If none of these options is successful, farmers can try to modify the manufacturer’s software, purchase software from a third-party, or attempt to develop their own.²³

Access to the tractor’s embedded software is also restricted through modifications of the ECU’s memory by the manufacturer. The computers have two types of memory volatile, present when the machine is powered on, and non-volatile, present even when machine is powered off. For both types, manufacturer modifications disable of the data ports in order to prevent farmers from accessing the machine’s embedded software.²⁴ By disrupting the electrical signals, farmers have once again found a way around the restrictions. Through a process called “fault injection”, farmers can “interrupt the ECU before it has a chance to send signals that would otherwise disable the BDM port, thereby allowing the user to connect to the port in its unlocked state in order to access the embedded software.”²⁵ Farmers can subsequently re-program the instructions of the ECUs memory.

²² *Petition for Proposed Exemption Under 17 U.S.C. § 1201*. USC Intellectual Property & Technology Law Clinic. (2015): 7.

²³ *Ibid.*

²⁴ *Ibid.*, 7-8.

²⁵ *Ibid.*, 8.

Based on investigation by those preparing the petition seeking exemptions for agricultural machinery, this method has become popular with those seeking a means of circumvention.²⁶ There are three categories of “fault injection”, non-invasive, semi-invasive, and invasive, that vary greatly in legality and ease of implementation.²⁷ The first, non-invasive, is argued to be the best option as it is relatively easy to achieve, low cost, and typically does not permanently alter the memory card’s physicality or functionality.²⁸ In contrast, semi-invasive fault injections are more expensive and require more expertise to achieve and invasive methods often cause considerable damage to the ECU.²⁹

Whether through memory modifications or third-party software acquisitions, farmers continue to seek ways to circumvent the manufacturer’s restrictions. Farmers want to get the most out of their tractors. Dan Alford, owner of a 1,000 acre farm in California, affirmed: "You spend so much of your time in agriculture fixing things...I’m of a size that it's more economically beneficial to me to fix as much stuff as I can myself".³⁰ They do not distinguish between the physical machine and software and, in many ways, they are right not to separate the two. These digital barriers make simple modifications to the physical machine, like changing tire size or installing wider axles, a software issue as the ECU must be altered to accommodate

²⁶ *Petition for Proposed Exemption Under 17 U.S.C. § 1201*. USC Intellectual Property & Technology Law Clinic. (2015): 8.

²⁷ *Ibid.*

²⁸ *Ibid.*

²⁹ *Ibid.*, 8-9.

³⁰ Sydell Laura, “DIY Tractor Repair Runs Afoul Of Copyright Law,” *National Public Radio*, August 2015, www.npr.org/sections/alltechconsidered/2015/08/17/432601480/diy-tractor-repair-runs-afoul-of-copyright-law.

these changes and keep the tractor functioning properly.³¹ To farmers, the software is an obstacle to overcome in order to improve the physical functionality of their tractors and given the problem-solving and pro-tinkering culture of agriculturalists, their pursuit of workarounds will continue despite the barriers, both technological and legal.

These pathways around the problem indicate both the severity of the issue created by embedded proprietary software and the level of software access that would be required for the tractors to meet the needs of the farmers. While designing software that gives different levels of access is feasible, the effort would have to overcome likely resistance by established manufacturers to maintain their dominance and profitability. Another route for designers to take is to help remove the policy level restrictions on software access that currently exist.

Currently, policy making is a messy, imperfect process and subject to competing economic forces. Designers can intervene at the policy level to ensure that the evolution of technology and variety of products are considered and can also respond to legislation that would require product makers to design products that are repairable or recyclable. They can inform grassroots advocacy groups and affected interest groups, in this case farming interests, of potential consequences of legislative or regulatory proposals submitted by equipment manufacturing or others, that have a strong self-interest in promoting their technologies and equipment.

³¹ *Petition for Proposed Exemption Under 17 U.S.C. § 1201*. USC Intellectual Property & Technology Law Clinic. (2015): 10.

In regard to the role of design in product development, *The Wall Street Journal* published an article, in September 2015, “We Need the Right to Repair Our Gadgets,” which described organized efforts on the part of consumers to fight back against planned obsolescence by fixing the technology already owned.³² This is accomplished by modifying the existing copyright laws or enacting new legislation aimed at exempting certain access-controlled products, such as agricultural equipment, from the DMCA’s purview. For example, at the state level in Minnesota, Massachusetts, and New York “Fair Repair” and “Digital Right to Repair” bills are being pushed to require “digital electronic product” makers to provide owners and independent repair businesses with service information, security updates, and replacement parts.³³

One of the grassroots coalitions leading the charge in this policy battle is the Digital Right to Repair Coalition founded in 2013. The Coalition is committed to establishing basic principles and informing people of their consumer rights, including the principle of repairable products, and advocates for a cradle to grave philosophy of product creation stressing that “designers should integrate design for repair and recycling principles into product development”³⁴. The product designers will be instrumental in implementing any legislatively created right to repair mandates that would integrate design for repair and recycling into product development. This is product design with a social purpose.

³² Fowler Geoffrey A, “We Need the Right to Repair Our Gadgets,” *The Wall Street Journal*, September 8, 2015, www.wsj.com/articles/we-need-the-right-to-repair-our-gadgets-1441737868.

³³ “Fair Repair,” *Digital Right to Repair*, Accessed November 9, 2015, www.digitalrighttorepair.org/fair-repair.

³⁴ “Coalition,” *Digital Right to Repair*, Accessed November 9, 2015, www.digitalrighttorepair.org/coalition.

Another role for the designer can be found within grassroots advocacy groups as a strategist who brings an understanding of the difficulties of navigating social and political. Numerous organizations, such as the National Grange and Electronic Frontier Foundation, are focused on fixing the problems associated with the DMCA at the federal level through the political and legal systems. One of the most harmful parts of the DMCA, the anti-circumvention provision (Section 1201), is the target of most of these interventions.³⁵ By statute, the Librarian of Congress and the Copyright Office review possible exemptions to Section 1201 so that users will be allowed to circumvent technical protections without violating the law. But exemptions can be proposed and considered only every three years.³⁶ While these reviews may help to resolve some of the DMCA's issues, some proponents of reform believe that the real fix is that Section 1201 should never apply where there is no infringement.³⁷

Legislative branches at both state and federal levels have recognized the imbalance in existing copyright laws and are seeking to find remedies. In April 2015, a new bill called "Breaking Down Barriers to Innovation Act" was proposed in the U.S. Senate.³⁸ This piece of legislation seeks to make the exemption process easier while clarifying and expanding the exemptions for reverse engineering, security testing, encryptions research, and strengthening

³⁵ Section 1201 of the DMCA states that "[n]o person shall circumvent a technological measure that effectively controls access to a work protected under this title." *Digital Millennium Copyright Act of 1998*. Public Law 105-304. *U.S. Statutes at Large* 112 (1998).

³⁶ CFR Part 201, Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies, *Code of Federal Regulations*, title 37 (2015): 8.

³⁷ "Unintended Consequences: Twelve Years under the DMCA." *Electronic Frontier Foundation*. March 3, 2010. www.eff.org/wp/unintended-consequences-under-dmca.

³⁸ *Breaking Down Barriers to Innovation Act of 2015*, HR 1883, 114th Cong., 1st sess., 2015, www.congress.gov/114/bills/s990/BILLS-114s990is.pdf.

privacy.³⁹ Some legislators, aware of the negative effects the DMCA on innovation and production, are trying to loosen the DMCA's choke hold on innovation at the policy level, asking the Copyright Office to analyze the impact of the law on "software-enabled devices", such as cars, phones drones, appliances and many more products with embedded computer systems.⁴⁰

In the case of the DMCA and farm equipment, manufacturers of tractors argue that because of their contractual arrangements with the supplier of the software, the farmer has acquired only an "implied license" to use such software.⁴¹ Consequently, this is the core policy issue: "[Farmers] that license, rather than own, the software have no right to make any changes to it for purposes of repair or improvement; instead, they must seek out dealers and suppliers that are authorized by the original manufacturers of the equipment to perform such work."⁴² Essentially, the software that is embedded in the tractors is protected by copyright law since these products contain copyrighted content.

An analogous issue arose concerning cellphone unlocking. Software in smartphones restricts them to operate only on certain cellular networks; if consumers want to use their phones with a different service provider, they would need to disable the "digital lock" that the software

³⁹Stoltz Mitch, "New 'Breaking Down Barriers to Innovation Act' Targets Many of DMCA Section 1201's Problems," *Electronic Frontier Foundation*, April 20, 2015, www.eff.org/deeplinks/2015/04/new-breaking-down-barriers-innovation-act-targets-many-dmca-section-1201s-problems.

⁴⁰ Walsh Kit, "Senators Probe Copyright's Impact on Software-Enabled Devices," *Electronic Frontier Foundation*, October 23, 2015, www.eff.org/deeplinks/2015/10/senators-probe-copyrights-impact-software-enabled-devices.

⁴¹U.S. Library of Congress, Congressional Research Service, *Copyright Law Restrictions on a Consumer's Right to Repair Cars and Tractors*, (2015).

⁴² Ibid.

places on the phone. However, if consumers attempt to take such action on their own, without their existing service provider's permission, it would constitute a violation of copyright law. Ultimately, this issue was resolved by the Unlocking Consumer Choice and Wireless Competition Act, passed by Congress in 2014, which allows consumers to unlock their phones to connect them to another wireless carrier.⁴³

The passing of the Unlocking Act by Congress in turn allowed for further strides to be made with respect to agricultural machinery. In April 2015, the Intellectual Property & Technology Law Clinic at University of Southern California submitted an exemption proposal to “allow circumvention of TPMs protecting computer programs that control the functioning of a motorized land vehicle, including personal automobiles, commercial motor vehicles, and agricultural machinery, for purposes of lawful diagnosis and repair, or aftermarket personalization, modification, or other improvement. Under the exemption as proposed, circumvention would be allowed when undertaken by or on behalf of the lawful owner of the vehicle.”⁴⁴ In October 2015, the Register of Copyrights “concluded that reproducing and altering the computer programs on ECUs for purposes of facilitating diagnosis, repair and modification of vehicles may constitute a *noninfringing activity* [emphasis added] as a matter of fair use and/or under the exception set forth in section 117 of the Copyright Act, which permits the owner of a copy of a computer program to make certain copies and adaptations of the program. The Register also concluded that owners of vehicles and agricultural machinery are adversely

⁴³ U.S. Library of Congress, Congressional Research Service, *Copyright Law Restrictions on a Consumer's Right to Repair Cars and Tractors*, (2015).

⁴⁴ Ibid.

impacted as a result of TPMs that protect the copyrighted computer programs on the ECUs that control the functioning of their vehicles.”⁴⁵ While there was strong opposition from equipment manufacturers, the exemption in large part was responsive in the case of agricultural equipment to the arguments of the farmers. While, the Librarian of Congress made some exclusions from exemption to prevent violation of EPA and DOT regulations, such as tampering with emission control settings, overall, the ruling proved to be a success for the farming community.

While the exemption process offers a chance to correct existing laws and regulations, it is a patchwork process. Policy makers tend to focus on correcting for specific circumstances, such as, in the case of the DMCA, protecting new media. However, in seeking to protect specific products and industries, the policies created may be so focused that as times goes on they are too broadly drawn which can prove detrimental to groups that were not part of lobbying for the DMCA. This presents an opportunity for designers to act as strategists, sharing their knowledge of potential futures and technologies in order to guide policy towards regulations that stimulate innovation instead of stifling its growth.

Like farmers, designers are problem-solvers. They can identify points of conflict in systems and products and develop solutions that not only solve the problems, but improve the context in which the issue was situated. If the methods for circumvention become legally permissible, designers involved in product and service development can maximize the efficiency

⁴⁵ CFR Part 201, Exemption to Prohibition on Circumvention of Copyright Protection Systems for Access Control Technologies. *Code of Federal Regulations*, title 37 (2015): 39.

and sustainability of the preferred modification methods, creating designs that are better informed by the behaviors of their users and allow for independent maintenance and repair.

Designers interested in strategic planning and social innovation can bring an important perspective to policy making that could greatly improve the process and ensure that future conditions are considered in the initial law-making process, especially where lawmakers' focus may be initially on protecting certain industries. By looking at all the systems, influences, and stakeholders involved over a longer span of time, designers can offer more foresight and future planning that can potentially account for the consequences of rapid changing and dispersing technology.

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Appendix

Figure 1. A chart illustrating the three components of culture.

Figure 2. A mapping showing the where tractors are situated in this issue, showing of the various interest groups and forces as they relate to the infrastructure, structure, and superstructure of the culture. The “design opportunity” space represents an area in which designers could develop potential solutions.

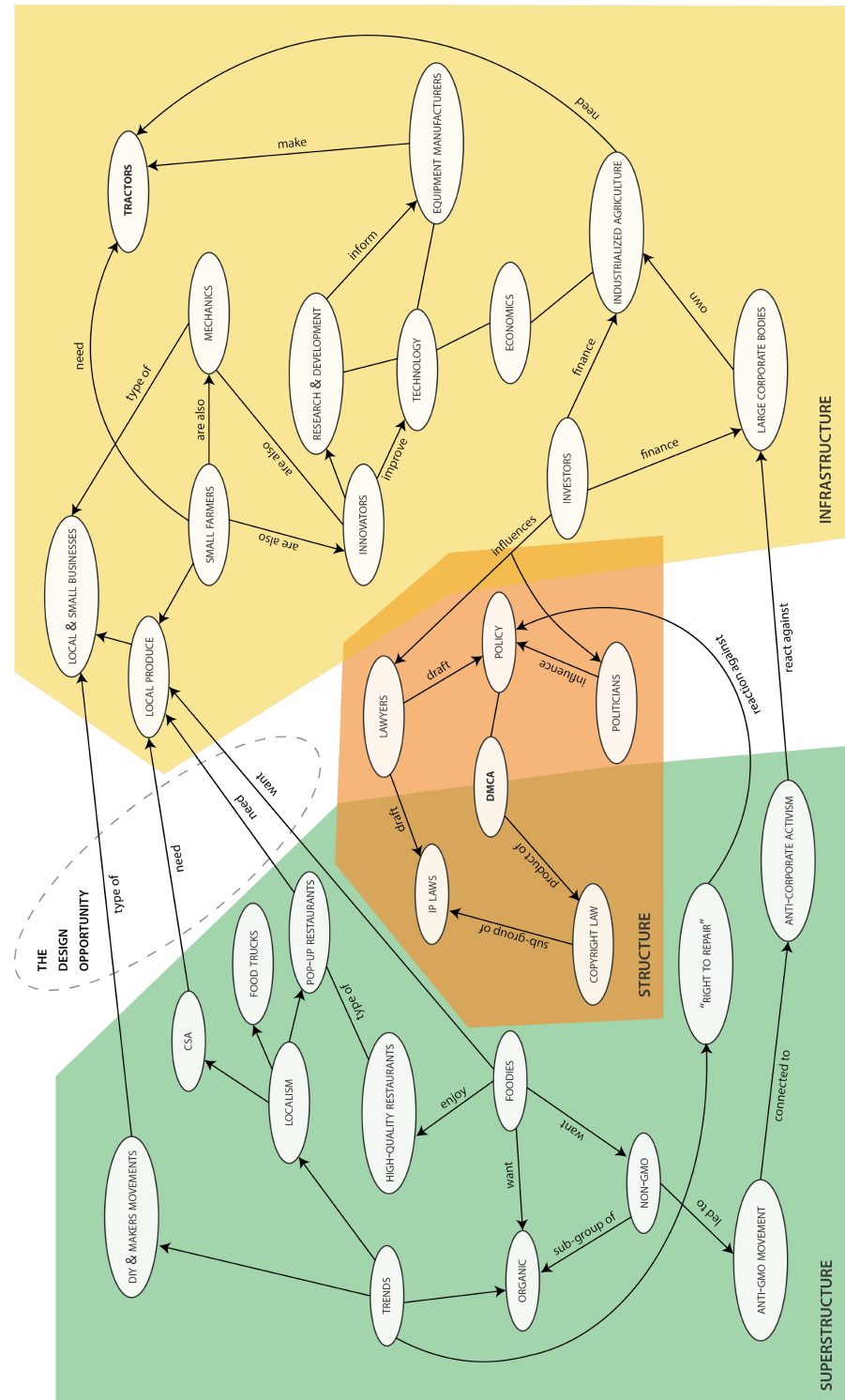




Figure 3. A chart illustrating how the three components of culture interact and the direction in which cultural change occurs.