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Applications of Projectile Motion in Real Life and Technological Advancements

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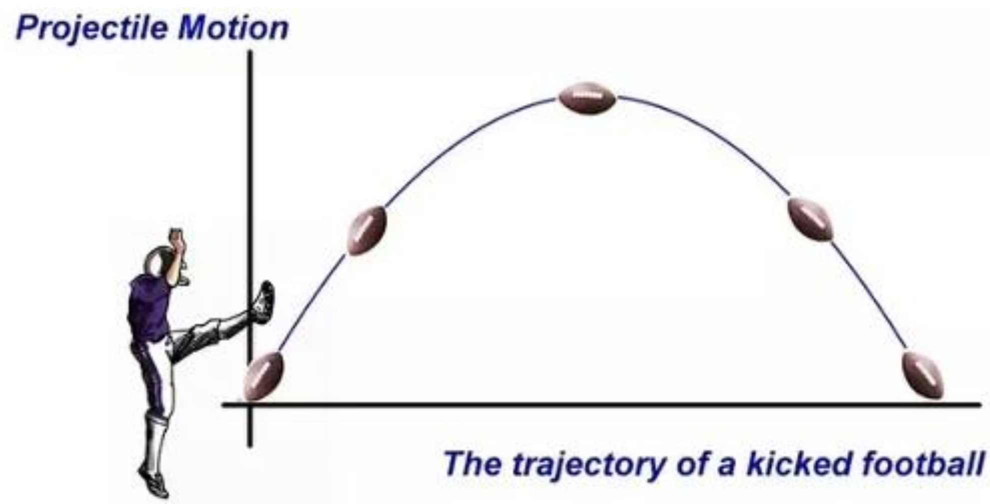
Abstract: *Projectile motion is a form of motion experienced by an object or particle (a projectile) that is projected in a gravitational field, such as from Earth's surface, and moves along a curved path under the action of gravity only. In the particular case of projectile motion of Earth, most calculations assume the effects of air resistance are passive and negligible. The curved path of objects in projectile motion was shown by Galileo to be a parabola, but may also be a straight line in the special case when it is thrown directly upwards. The study of such motions is called ballistics, and such a trajectory is a ballistic trajectory. The only force of mathematical significance that is actively exerted on the object is gravity, which acts downward, thus imparting to the object a downward acceleration towards the Earth's center of mass. Because of the object's inertia, no external force is needed to maintain the horizontal velocity component of the object's motion. Taking other forces into account, such as aerodynamic drag or internal propulsion (such as in a rocket), requires additional analysis. A ballistic missile is a missile only guided during the relatively brief initial powered phase of flight, and whose remaining course is governed by the laws of classical mechanics. The elementary equation of ballistics neglect nearly every factor except for initial velocity and an assumed constant gravitational acceleration. Practical solutions of a ballistics problem often require considerations of air resistance, cross winds, target motion, varying acceleration due to gravity, and in such problems as launching a rocket from one point on the Earth to another, the rotation of the Earth. Detailed mathematical solutions of practical problems typically do not have closed-form solutions, and therefore require numerical methods to address.*

Keywords: *projectile motion, ballistic, trajectory, mechanics, closed-form, numerical, aerodynamic, trajectory.*

Introduction

Projectile Motion, by definition, is the motion of an object thrown or projected into the air, only subject to acceleration due to gravity. The motion has a constant horizontal velocity combined with a constant vertical acceleration caused by gravity. This is usually thought of as the motion of a ball thrown while playing catch[1], the arc of a basketball shot, or a kicked football trajectory.



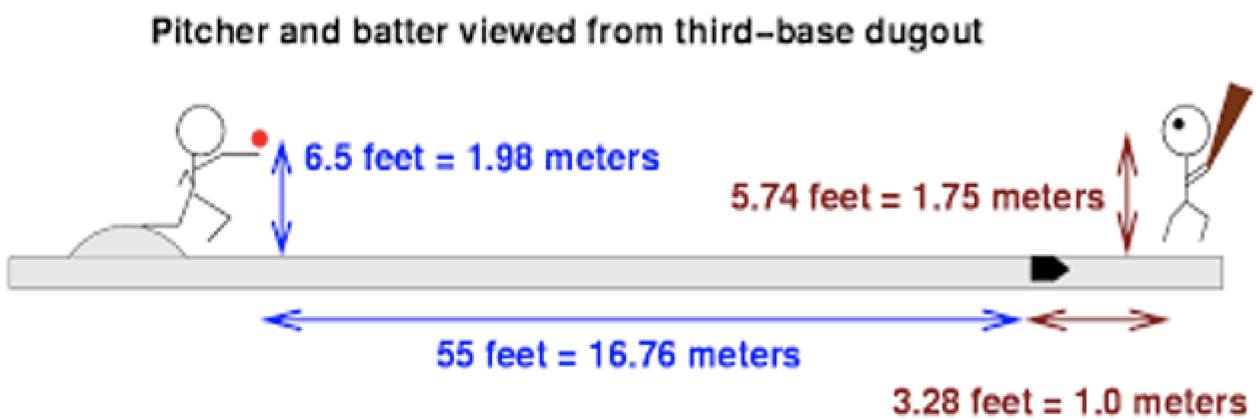
However, there are many other instances where projectile motion is applicable, whether it is in daily life or in technological advancements. Here are some of the applications of projectile motion.[2]

1: Sports

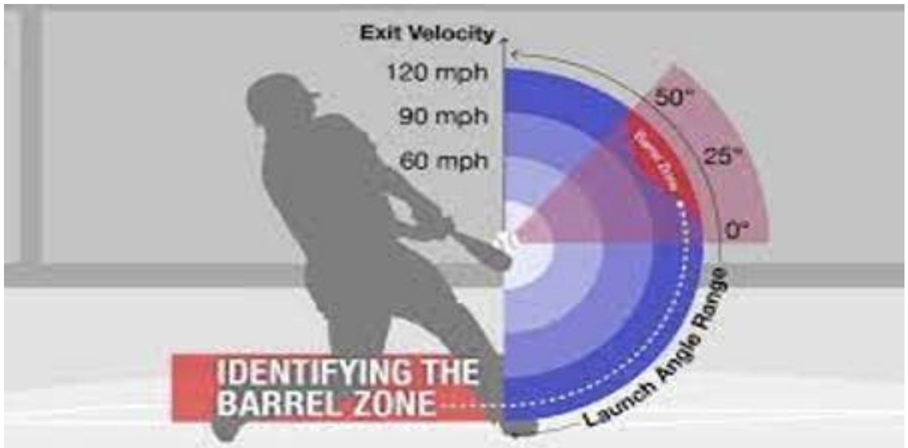
Projectile motion is very common in sports, since most sports involve the motion of a projectile (usually a ball). By using physics, we are able to determine the optimal angle of a ball's flight in order to maximize speed or distance.[3]

Baseball

Projectile motion is applicable in both throwing and hitting. A thrown ball undergoes projectile motion when it is mid-air since the only force that affects the ball is the acceleration due to gravity. Baseball analysts can analyze baseball pitchers using an understanding of kinematics and projectile motion. A variety of factors will go into the trajectory of a pitch, including a pitcher's height, arm angle, and the spin being applied to the ball. All of these, along with kinematics, are used to determine how fast a pitch is being thrown relative to the batter's eye. Typically, a 90 mph pitch takes 0.4 seconds to reach the batter from around 55 feet (subtracting the pitcher's stride from the regular 60 feet); this can be calculated using kinematics.[4]

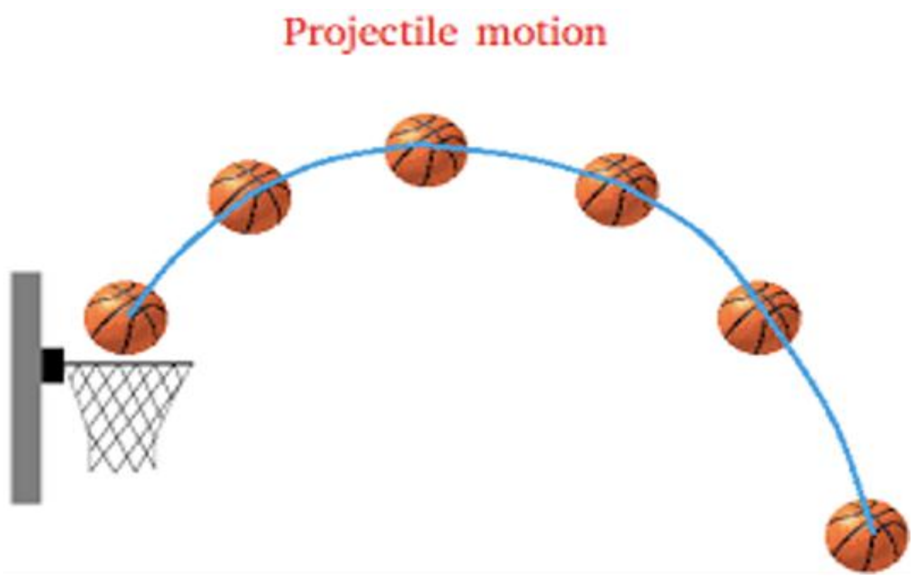


In terms of hitting, advanced analytics like to use "launch angle" as a good indicator of the optimal angle that a ball should be hit. Launch angle is the angle at which a ball exits the bat as soon as they contact each other. The best launch angles, which allow for line drives and home runs, are calculated to be around 10–30 degrees North of East, relative to the bat. This allows for the most optimal ball flight, usually necessary to hit the ball over 325 to 400 feet over the fence.[5]



Basketball

Another example of projectile motion in sports is in basketball. For a basketball shot to enter the hoop, the basketball must be shot at a certain angle with a certain amount of force. The optimal angle of a shot will vary depending on the height from which the ball is shot and the player's distance from the hoop. According to Professor John Fontanella, the ideal angles from the free throw line will vary from 48.7 degrees to 52.2 degrees, with shorter players requiring a higher arching shot to compensate for the height difference of the initial release. This angle considers both the arc of the basketball and the force required to shoot the basketball. The higher the arc, the more room for error a shooter can have[6]. However, a higher arc will require more force to allow the ball to reach the hoop. As well, the force of gravity will increase the speed of the ball as it falls. This is why you cannot simply shoot the ball with a near-vertical degree angle and expect more shots to drop in on top of the amount of strain you will put on your body by using more force to shoot each time.[7]



2: Programming/Animation

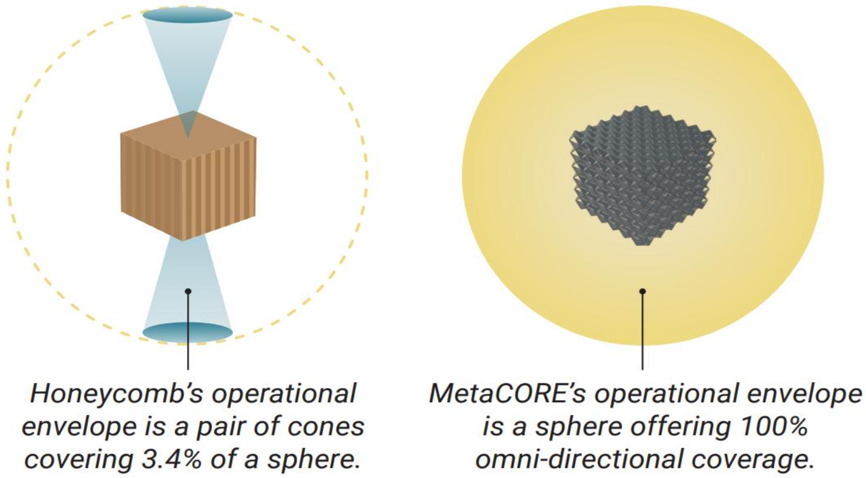
Another example of the application of projectile motion is in programming. The challenge for modern-day programmers and animators is to model real-life physics as accurately as possible, whether for a tv show or a video game. Great video games attempt to follow them as accurately as possible, whether it is the physics of a baseball being hit or the physics of a person falling a certain height. For the games to be enjoyable, they must be as close to reality as possible; a golfing game would not be fun and realistic if the ball were being driven 1000 yards.[8]

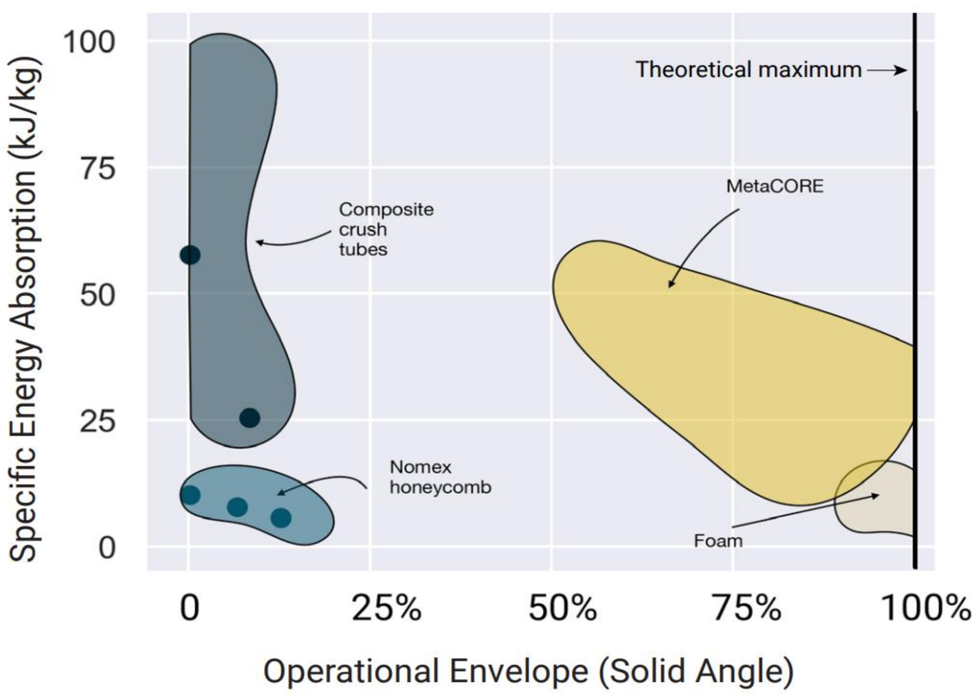
3: Other applications

Other examples where projectile motion may be applied to real-life are in certain appliances and the military. Looking at appliances at home, objects such as water hoses or water guns involve projectile motion. Instead of a ball, the “projectile” in question is water. However, it is still an object in the air, only affected by gravity when released, meaning it is considered projectile motion. The distance that the water will travel once it exits the hose depends on the hose’s angle and the force that the water is being exerted. The force that the water can exert is not very high for the product in hand to be safe and helpful in watering plants, so the distance that the water can travel is not very far. However, the angle of the hose can be changed to reach certain parts of the garden/soil. By optimizing the water’s launch angle (45 degrees), the water can travel as far as possible, minimizing the distance you need to walk to water your entire garden.[9]

The military and the manufacturing of their weapons also involve projectile motion. A bullet, when shot from a gun, is considered a projectile in the air. The bullet will travel at a much higher speed than the water from the water hose, meaning it will travel a much further distance and will be less susceptible to acceleration due to gravity, relative to how much it travels horizontally. However, it is not like gravity is not affecting the bullet. Thus, manufacturers of guns attempt to maximize the speed that the bullet is released from the weapon while minimizing the gun’s amount of recoil. This would help soldiers maximize aim while reducing other factors that would cause them to be inaccurate.[10]

Discussion
Technological advancement-1
Achieving long distance aerial delivery





MetaCORE is a lightweight energy-absorbing replacement for honeycomb that offers 30x improved performance without increasing weight, costs, or logistical challenges.[11]

Focus Area: Soldier Lethality and Survivability through Expeditionary Force Sustainment.

Technology Statement: We make lightweight high-performing energy absorbing materials to mitigate damage from unpredictable high-impact loads.

Impact Statement: "Every pound of payload successfully delivered is another pound of food, water, and equipment for the Soldier."

Problem Statement: Air dropped payloads require impact-mitigating solutions to ensure cargo is delivered 100% mission capable. Current missions use cardboard honeycomb as an energy absorbing device to "soften" the landing. The operational envelope of cardboard directly constrains payload size, weight, drop times, horizontal glide distances, and speed. Future missions involving large horizontal glides are outside the operational envelope of cardboard honeycomb due to its poor shearing properties[12]

Solution: MetaCORE is an advanced material with isotropic energy absorbing properties that eliminates the 200% to 600% asymmetry in cardboard honeycomb's material properties. It was developed by Multiscale Systems under a NASA SBIR Phase I/II contract as a lightweight low-cost material for non-defense aerospace and ground vehicle applications (est. ~$1Bn commercial market). With some modification to the existing manufacturing process, it would be an ideal energy absorber for vastly expanding airdrop operational envelopes. This is a dual-use technology with TRL 4 for aerial delivery applications.[13]

Needs: Manufacturing MetaCORE from natural fibrous/pulp materials is required to be costcompetitive with current cardboard honeycomb and to achieve biodegradability/flammability for easy disposal. Low throughput manufacturing is currently feasible, but further development is required to scale up production.

Value Proposition:

- 30x increase in the operational envelope for impact mitigation compared to honeycomb (see figure below).
- Enabling longer glide distances and larger horizontal speeds necessary to overcome A2/AD threats.
- Manufacturable in a format compatible with existing rigging specifications and agnostic to cargo type.
- Lightweight material increases expeditionary value.
- Natural fiber/pulp-based fabrication adds no additional signature and requires no power source.
- Biodegradable polymer formulation enables heavier payloads while reducing total system mass and volume.[14]

Fast Facts About the Technology and Team:

- Material design technology discovered and developed in the Physics Departments of Cornell University and University of Massachusetts, Amherst, as well as Harvard University's Wyss Institute.
- Multiscale Systems is a small, domestically owned business in the ASA(ALT) xTechSearch 4 and Innovation Combine cohort of "non-traditionals" with disruptive new technologies responsive to Army modernization priorities. We have experienced stable growth since forming in 2018 by developing advanced materials for dual-use applications.[15]

Results

If the risks can be managed, it is plausible that over the next twenty-five years a panoply of technological advances will vastly improve human welfare as well as help set the world's development on a sustainable course. However, as history demonstrates, the availability of a particular scientific discovery or innovative technology is no assurance that its potential will be extended into useful applications, nor that it will diffuse widely or to those who might use it most productively. Reaping the rewards and reducing the dangers generated by technological advances depend on a complex interaction with underlying economic, social and political conditions. Realising the fruits of socio-technical dynamism demands careful consideration of two dimensions: first, how various socioeconomic environments lead to differences in the pace and direction of technological innovation and diffusion; and second, what the implications are of the uses and spread of new technologies for the economy and society. The framework conditions influencing the rate and distribution of technological advances can be broken down into three general categories: micro, macro and global. Socio-economic factors at the micro level involve, on the one hand, the specific institutional and organisational patterns of families, households, enterprises and government agencies, and on the other, the decisions made by individuals in their roles as members of a household, workers, managers, civil servants or politicians. Macro factors are the overall socio-economic circumstances within which households and enterprises must operate. Here, the general conditions and technological predisposition of product, labour and capital markets are shaped by national monetary, fiscal and regulatory policies that can alter the predictability of borrowing conditions (interest rates), price levels, competitors entering a market and changes in employment rates. Lastly, global framework conditions relate to the management of, for example, the international system of trade, investment and technology flows and planet-wide environmental interdependence. There can be little doubt that the rates at which ideas, technology and competitive pressures diffuse around the globe – not to mention the extent of cooperation to reduce conflict and environmental pollution – will play a major role in determining future socio-technological trajectories. Micro, macro and global framework conditions can thus be seen as either favouring or impeding technological dynamism. Circumstances where the framework conditions are all favourable to technological dynamism are much more likely to open up the possibility of significant changes in socio-technical patterns. Alternatively, should the framework conditions be more adverse to such change, there is less chance that there will be a break from current economic and social structures. There is no one best formula for encouraging socio-technical dynamism. However, a useful distinction can be made between those framework conditions that are likely to be more supportive of major socio-technical transformations (with potentially strongly positive leaps in society's capacity to address challenges and reap rewards) and those that are more linear and remain entrenched in existing patterns[16]

Micro-level dynamism and resistance to socio-technical change The micro level prospects for twenty-first century technologies are mixed. There are a number of changes taking place in the way that firms and households organise work and everyday life that seem conducive to technological innovation and diffusion. On the other hand, there could be an important clash between the radical possibilities opened up by technological change and time-honoured traditions, habits and relationships. Adopting new attitudes, accepting alternative approaches to risk management and equipping people for different decisionmaking structures is rarely straightforward. The chapter by Meinolf Dierkes, Jeanette Hofmann and Lutz Marz examines these complex and sometimes cyclical processes by looking at the prospects for two important sectors that are at different stages of acceptance and diffusion. One is the mature automotive industry and the other is the booming Internet. A third example is included here to provide an even fuller picture: the transitional health sector. Future prospects for the automotive sector provide a good illustration of the forces that give rise to both dynamism and resistance at the micro level. What were, almost a century ago, the automotive sector's great contributions to technological dynamism – the semi-automated assembly line and the vision of the automobile as a mass consumption item – could well become some of the primary constraints on tomorrow's innovation. Like Frederick Taylor's approach to the time-motion division of labour in the steel industry, Henry Ford's techniques of mass production spread throughout the

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economy in ways that acted as a catalyst for developing both new production technologies and new products. The combination of more efficient organisation of production with advancing technology provided a massive stimulus to innovation, competition and productivity throughout the economy. Consumers, too, became caught up in this vision of mass production, mass consumption. The household integrated a large range of new products and ways of conducting daily life. This involved not only driving the car to work, to the shopping mall and on the family vacation, but also using washing machines, refrigerators and TVs. The search for solutions to social problems also succumbed to the production methods and product design approaches of the automotive era, with huge mass production, mass consumption public programmes even in health, education and welfare. For many years this was a transformative paradigm that propelled productivity forward and inspired major technological advances. Within the confines of this automotive vision of production, consumption and mobility, there will continue to be considerable scope for iterative innovation. Competition is likely to continue to press firms to improve products, as will initiatives to address the important problems posed by automotive pollution, congestion, and safety. Major strides will probably occur in the technologies used to power vehicles, co-ordinate traffic and protect drivers.[17]

The sector will continue to advance through innovations such as ‘‘smart’’ highways, hybrid electric vehicles, extensions of ‘‘lean production’’ methods and, of course, the computerised car with GPS (satellite-based global positioning system) for navigation and a full range of telecommunications links including Internet-based data, voice and video. However, unless there is movement beyond the automotive paradigm, the opportunities for more radical organisational breakthroughs within the factory, the home and society at large could be missed. For instance, realising the potential to reconfigure where and how people work and live in order to greatly reduce overall environmental carrying costs such as those incurred by current transportation systems will, in all likelihood, require fairly decisive breaks with past sociotechnical patterns such as commuting to the workplace and driving to the shopping centre.

In contrast, the Internet could pioneer a significantly different vision of work and society. That vision is rooted in, and hence naturally tends to propagate, a form of organisation embodying a more decentralised responsibility and power structure. One way of grasping how the Internet introduces new possibilities is by comparing it with a conceptually similar but technically different electronic network that is now vanishing: electronic data interchange. EDI took a proprietary approach to connecting enterprises, primarily supply networks in manufacturing and finance, in order to improve co-ordination. Pushed forward in the 1970s and 1980s, these exclusive systems were incompatible between vendors, and tended to be expensive and inflexible. Today, in an amazingly short time, the Internet has eclipsed most proprietary EDI systems. Internet technology, initially developed through public sector initiative, provides free and open access to a valuable asset, a common standard. A powerful economic imperative is unleashed by the Internet’s technology: the increasing returns to scale of both networks and a universal, open set of standards. Collaboration not isolation, extension not restriction – those are the watchwords of the Internet. Indeed, one need only consider the rather sudden enthusiasm with which usually irreconcilable competitors work together to ensure that the Internet becomes a seamless, open space for commerce. National governments and international organisations from the OECD to the W3C (World Wide Web Consortium) are striving to make sure that the Internet becomes a widely shared and level playing field free from obstacles to electronic commerce, e-mail, and the open flow of information. Compared with the hierarchical, largely centralised models of organisation dominant in most private and public sector places of work (and even in many households), the Internet is an anarchistic, overly decentralised and disorganised (virtual) place. It is an ocean of information connected according to the non-linear rules of hyper-links. It is highly efficient for sharing ideas and taking the initiative to make spontaneous connections oblivious to distance, time zones or preconceptions. It is in marked contrast with the more rigid industrial paradigm of mass production and mass consumption. The Internet thrives in a world where intangible assets are more important than yesterday's fixed assets and digital copying means almost zero-marginal cost reproduction. As a result, the Internet has the potential to transform completely many of the institutional and behavioural patterns that have characterised at the micro level both the supply and demand sides of OECD economies. On the supply side, new forms of work organisation, product development and distribution, market entry and collaboration are emerging. On the demand side, consumption is beginning to shift from passive to active modes. Entirely new business models are being invented in order to exploit these new conditions profitably. Individuals and firms are using the Net not only to actively seek existing products but also to initiate the production of items they conceived. The consumer is beginning to take on a key role formerly reserved for the producer. If this paradigm shift continues to diffuse, there is a chance that across a wide range of activities the value-added chain may be turned upside down. Sustaining and extending such a radically different culture will take time, and could even fail.[18]

True decentralisation of decision-making and co-ordination that goes beyond telework just to save office space and reduce commuting will require individuals to take responsibility throughout the day, from the moment they choose (as producer/consumers) their personally unique breakfast cereal mix to the innovation they dream up (as worker/entrepreneur) in co-operation with a customer that afternoon. This is a daunting challenge. People are naturally resistant to giving up familiar strategies for achieving economic and social success, managing risk and assuring continuity. Although it may at times only be a question of perception, of how someone looks at change – ‘‘is it a threat or an opportunity?’’ – a new paradigm can be very disruptive. The demands of networked ‘‘dynamic reciprocity’’ go well beyond the roles people are trained to perform and the ways of learning that have been fostered by schools, offices and most homes. For all the potential of the Internet paradigm there are many constraints, not least of which is the powerful tendency to reimpose traditional methods by simply grafting the old patterns onto the new. These counter-currents can be seen in all areas, from the private firm or public agency that merely uses the Internet to de-layer operations without changing the organisational culture, to misconceived government policy initiatives that impose industrial era solutions on knowledge economy problems.

Conclusions

Healthcare is already in transition. In most OECD countries the traditional approach to human health leaned heavily on the industrial mass production and mass consumption model, with the hospital as factory and the patient as passive consumer. The paradigm did lead to tremendous gains in reducing the mortality and morbidity associated with disease and accidents. Recently, however, serious limits have emerged in terms of both cost and effectiveness. Reform is under way, with considerable iterative technological and organisational progress already made and even more expected when it comes to controlling costs and improving delivery methods. What is less certain is the extent to which the combination of info- and bio-technologies will actually transform the current medical services sector into a decentralised, active source of preventative maintenance of more than physiological well-being. As indicated earlier, there is a possibility that the breakthroughs expected in understanding genetic and biological processes, along with the power of computing to monitor, store and assess huge quantities of biodata, could lead to major advances in the identification of hereditary and environmental factors likely to affect people's health. This potential for much greater individual control and prevention of health risks could bring with it a redistribution of power and transformation of the institutional and behavioural context. There are, however, many micro-level obstacles to such a transition. Foremost, perhaps, is the fear and ignorance that still pervade most people's view of their health. The notion of taking personal charge of disease prevention, diagnosis and most treatment is not yet a widely shared vision in today's society. There are ethical and knowledge barriers, but there are also a wide range of institutional and entrenched interests that are likely to oppose a change in the sources of health-related information and decision-making. Here home-based real-time diagnostic and treatment technology, by making health outcomes much more transparent, could play a key role in reducing risks, opening up new markets and enabling institutional and behavioural change. In a world where health information is much more understandable and reliable, individuals can be expected to begin making their own choices. This, in turn, is likely to open up new markets and spur the development of new products that would allow people to benefit from the advances of info- and bio-tech. Technological advances, along with changes to the regulatory systems that protect and concentrate the present patterns of control of health-related information, could turn patients from passive consumers to active controllers. They could also turn medical monopolists into open competitors and doctors themselves into a new breed of practitioner. Overall, these kinds of radical, technology-enabled changes in the microlevel organisation of work or in the familiar model of passive mass consumption could seriously disrupt or destroy a range of established mechanisms for managing or reducing the costs and risks of organised activity. Some of the most basic assumptions that underpin what people know and expect in the workplace and the home could be called into question. For instance, with the explosive development of technologies such as the Internet, there is likely to be an accelerating trend away from the reassurances, subtle information-sharing and planning assumptions that were once offered by stable career patterns, fixed responsibility pyramids, familiar local shops, and face-to-face encounters at work or in the schoolyard or doctor's office. Continued ''dis-intermediation'' – a term that refers to the radical changes that occur in the mediating role of the retailer or university when bypassed by the establishment of direct links between the producer and consumer, student and teacher – will in all probability compound the disruption of established micro-level organisational patterns.[19]

Meeting the challenge of nurturing an innovation-driven economy and society will likely require equally inventive policy initiatives. For many commentators there will probably need to be a major overhaul of competition and intellectual property laws and administration to take into account the greater importance of intangible assets and global markets. The Internet's extra-national characteristics will also demand novel policy responses. New ground will have to be broken in order to provide the policy frameworks that enable existing technologies to provide every person with the verifiable cyberspace identity needed for voting or sharing medical data. Breakthroughs will also probably be needed in managing global issues like climate change and in pursuing the development and diffusion of technologies that ease some of the negative trade-offs between economic growth and environmental sustainability while at the same time capitalising on the possible synergies. As micro-level decentralisation alters the mass production/mass consumption paradigm, new forms of risk-sharing, information verification and spontaneous co-operation will need to emerge. Rules – in some cases, creative regulatory initiatives – regarding electronic commerce will probably be essential for encouraging both the global functioning of existing markets such as insurance or equities, and the development of entirely new transactions such as the sale to business database services of private personal information (e.g. individual preferences, income, purchasing intentions, evaluations of products or brands).[20]

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