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Disruptive Technologies and Their Putative Impacts Upon Society and Aerospace- Entering The Virtual Age

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Disruptive Technologies and Their Putative Impacts Upon Society and Aerospace
- Entering The Virtual Age

Dennis m. Bushnell

Introduction

Developments in technology over the recent decades have been extraordinary. They include the IT, bio, nano, and now quantum and energetics technology arenas and their many combinatorial interactions and impacts. In the main, these are at the frontiers of the small and in a combinational, synergistic feeding frenzy with each other. They fall under the broad category of Disruptive Technologies and have greatly altered society. The outlook for the runout of these and other technology developments augers mid-term to later alterations in components of the human existence theorem, including the requirement to work for our living and our physiological makeup and longevity (Ref 1). The IT revolution began in the 1950s with the development of solid-state electronics. The biologics revolution began later in the 1960s and 1970s with DNA and genomics, and the nano revolution in the 1990s with self-forming nano systems and carbon nanotubes. Quantum technology is now developing rapidly, aided by enabling nano systems, and the energetics revolution is providing ever more efficient and less expensive renewable energy sources. The IT revolution has produced improvements of an astounding eleven orders of magnitude in computing speed since the late 1950s. As we shift from silicon to biological, optical, nano, molecular, and atomic computing, improvements of some 4 orders of magnitude are evidently possible from either optical or DNA computing [Refs 2 and 3], then there are combinatorials. Then there is quantum computing, under development worldwide for an increasing number of applications and proffering phenomenal capabilities. The current fastest computers are considerably beyond human brain speed. Machine intelligence is developing well after decades of inadequate machine capability, now no longer the case, and a detour into expert systems. Researchers in machine intelligence are now pursuing deep learning approaches using neural nets, which are proving to be extremely useful. Some believe the frontier of potential human-level machine intelligence may be found in biomimetics and brain-emulation approaches. There is even a possibility of "emergence"—i.e., when the machine intelligence is complex enough that it "wakes up," as when human intelligence emerged via evolution during the million-plus years of the hunter-gatherer epoch [Ref 4]. In fact, some posit that human intelligence can be improved upon and is only a cul-de-sac of what is conceivable. The IT revolution has produced massive changes in human society and economics — from the Internet, enabling the rapid expansion of knowledgeability (and even what is knowable), to an increasingly pervasive trend of "tele-everything." The extraordinary compilation, storage, and availability of truly massive amounts of information could, when combined with AI and under the mantra of "big data," greatly improve many of our technical and commercial processes and their content including elucidating new heuristic governing laws.

The IT revolution will also accelerate the expansion of robotics' capabilities, which are on a clear path to pervasive autonomous systems. The machines are rapidly supplanting humans in ever more areas of employment. They are proving to be more productive, less expensive, and—in a growing number of areas—more capable than humans.

The development of five-senses virtual reality is a major advance in human–machine communications that bodes well for accelerating the tele-everything trend. IT-enabled 3-D printing is rapidly changing the manufacturing landscape from central factories that employed humans to robotic home fabrication. This transition has potential major consequences for the field of aeronautics and space exploration in such areas as alternatives to transporting cargo and manufacturing using in-space resources.

What is evolving is a global brain, via the Web. When combined with manufacturing via on-site printing, this global brain is enabling a planet of inventors—both human and, increasingly, machine. The impacts are literally life changing and are occurring essentially simultaneously with many other societal issues including climate change and ecosystem degradation.

Most of the current rational for commercial space development focuses on telecommunications, a major industry that is based upon exploiting space as the positional high ground. Other IT-enabled computational sciences—e.g., structures, materials, fluids, systems—constitute the design backbone of aerospace. Simulation technology is rapidly evolving into a virtual flight capability resulting in less physical testing and more computation. The number of wind tunnels and wind tunnel test hours is decreasing. Aerospace has, from its inception, been married to IT technologies, including for controls and navigation, communications, and design. More than 80% of safety issues in aeronautics are due to human factors. Autonomous flight would be expected to have a better safety record. The technical capability is in hand now—and will improve going forward—for autonomous flight for uninhabited air vehicles (UAVs) and eventually autonomous personal air vehicles (PAVs), or UAVs carrying passengers. The estimated markets for such robotic air vehicles are massive but require an autonomous air traffic control (ATC) system to realize. Many redundant, fail-safe IT technologies (e.g., sensors, navigation, communications, actuators/controls, machine intelligence, computers, software, etc.) are either here or on the horizon to produce an ATC system enabling millions of autonomous vehicles in controlled air space. Given such an ATC system, quiet vertical to short takeoff and landing (VSTOL) vehicles for human-sized and smaller-payload autonomous flight could operate off the street in front of an individual holding. Applications would include delivery, a wide variety of service and commercial functions and personal transportation, with an estimated worldwide market on the order of a trillion dollars per year, mostly from PAVs. (Ref. 5)

The above addressed mainly the progress and some selected impacts of IT. The other major disruptive technologies could be discussed in a similar fashion. The IT "Technology Revolution" began earlier and has probably thus far had the greatest impact upon society and Aerospace and was used as the exemplar of Disruptive Tech Developments over these last decades. A partial listing of the current operative Disruptive Technologies includes: (Refs. 6-8)

- Trusted autonomy
- Quantum computing
- Quantum vector/scalar potential communications (non electromagnetic)
- Increasingly inexpensive renewable energy and energy storage
- Syn. Bio/Crisper/personalized med, anti-aging, etc.
- Smart everything, IOT
- AI writ large/autonomous robotics
- Miniaturized, ubiquitous, networked nano/quantum sensors
- Brain/machine communications/interactions
- Virtual presence, VR, holographic projection, digital reality
- Nuclear battery and positron storage
- Printing/materials with architectural sub elements & superb microstructure
- Electric UAS, electric transportation writ large
- Machine ideation
- Halophytes, salt plants grown on wastelands using seawater for land, water, food, energy, climate
- DIY technologies, at home tele-everything, distributed energy generation/manufacturing/printing, and food production

This report will consider the developing nature and combinational/systems level capabilities of these and other disruptive technologies as they could alter many aspects of society and aerospace going forward, including:

- The AI/sensors/computing nexus
- Virtual living/tele-everything
- Increasing cyborgism
- High tech DIY/back to the land
- Rise of the robots
- The bio revolution writ large
- Halophytes as a solution to land, water, food, energy and climate
- The renewable energy/storage revolution, solving climate
- Printing manufacture/advanced materials

Also included is a summation of the putative system of systems overall major to massive disruptive technology engendered potential alterations of society and aerospace, AKA – The spectrum of "Where is it all going? (Ref. 9). We are rapidly transiting from the IT Age and entering the Virtual Age, with major shifts to direct brain to machine interaction, humans merging with machines, immersive digital reality, autonomous robotics, tele-everything, a global sensor grid and a shared global mind. The major existential issue will then become "Whither Humans"?

The AI/Sensors/Computing/Web Nexus (Refs. 5, 10)

The AI Technology Revolution has thus far resulted in computing machines sufficiently capable to enable serious development and increasing applications of learning AI via neural nets. Learning AI is only one approach to AI; others include the Human Brain Projects which are nano-sectioning the neocortex with an eye to replicating it in silicon, etc. This widespread effort began with the IBM Blue Brain Project and is making progress. The current learning AI requires ”big data”, which can be supplied by extant compilations, the web, and sensors. Sensors are miniaturizing rapidly now, increasingly harvesting their energy and reducing in cost, and being placed nearly everywhere (e.g., land, sea, air, space, appliances, etc.). Some project a global sensor grid composed of trillions of networked sensors is not that many years away from being produced. With such a surfeit of data available to AI, others are projecting a global brain, an initial instantiation of which is the addition of AI to Google.

Steven Thaler has invented an imagination engine where machines at the systems/applications level, using superb speed and knowledgeability, are able to rapidly generate and evaluate, via systens considerations, huge numbers of quasi random [involving related technical aspects] combinatorials and execute brute force machine ideation. With machine ideation to handle the unknown unknowns, trusted autonomy will be available sooner.

The web and AI are enabling smart everything/anything, including the IOT and autonomous robotics. Also, by producing a second intelligent species (e.g., autonomous AI robotics), this nexus is increasingly replacing humans in the labor market, including alteration of the need for humans in space. Other impacts of all this include the death of privacy, superb machine creativity and design/operation, and an existential vulnerability to nuclear EMP and major solar storms. A huge mortality is projected by the Congressional Nuclear EMP commission of the latter due to the complete societal reliability/dependence on electrons/electricity [ref. 11]. The apparent solution to this is to develop, much faster, distributed energy generation, employing less costly renewables and storage at the user site. In summary, increasingly, decisions are made by nonhuman algorithms, ubiquitous autonomous robotics are subsuming much of employment, and a massive societal vulnerability (e.g., electron vulnerability to EMP/solar storms, cyber, jamming, etc.) has developed due to nearly complete dependence on electrons.

Virtual Living, “Tele-Everything” (Refs. 9, 12)

As IT as a whole has developed these past decades, society has morphed into an increasingly tele-everything operational lifestyle. This started many years ago with tele-communications, the telegraph/telephone initially, and then tele-entertainment, the movies and television. These were pre the IT revolution, which began in the late 1950’s. Since then, tele-applications have become pervasive, including tele-commuting/tele-work, tele-travel, tele-med, tele-ed, tele-shopping, tele commerce/banking (endemic) , tele-politics, and, especially via smart phones, tele-socialization, and with on-site printing and manufacturing, tele-manufacturing. This tele everything shift is enabling the population to increasingly live wherever it wants. Distance has a different meaning specific to the type of telework. Those tele-working seriously, as do many in the gig economy and otherwise, are more distance agnostic.

Emerging technologies conducive to tele-everything include VR, augmented reality and 5 senses VR, as well as holographic projection. Video conferencing interactions are now of a good enough quality that body language, which comprises much of our communications, can be discerned, thus providing the missing ingredient for even more serious utilization of tele-travel and tele-conferencing. Digital reality/immersive presence technologies have developed along with cost reductions, increasing bandwidth, storage, computing speeds, and recently, brain-to-machine communications. Digital reality is becoming a serious competitor to physical business travel and increasingly leisure travel.

The benefits of digital reality/tele-travel compared to physical travel include: social distancing/working at home during pandemics, major cost reductions, time savings, less airport security and other hassles, can literally be anywhere at any time with multiple contacts/places/meetings on a given day, lack of physical and health risks, no overcrowded sites/venues, greatly reduced CO_2 emissions/water above the tropopause/thin cirrus clouds engendered climate forcing, obviates crowds, enables travel by the infirm, provides superb educational experiences, and with current technology, provides the nonverbal/body language portion of communications all with far less time spent away from home/family.

The virtual meeting market was, pre Coronavirus, some $4B/year, and for most business purposes is now considered equal to onsite/physical travel engendered meetings. Tele-travel provides overall greater efficiency, quality of life, and better work/family life balance. As we enter the post Coronavirus period, which is typified by straited economics, there is a need to rapidly “catch up.” There has been extensive, largely successful, utilization during the period of COVID social physical disengagement of virtual/tele-interactions for nearly everything. Therefore the expectation is that utilization of digital reality and tele-everything will be accelerated going forward, with resultant potential impacts upon aerospace. Major expected impacts of further accelerated shifts to digital reality/tele-travel due to the aftereffects of the Coronavirus experiences include reconsideration of the functions of humans in space, which cost orders of magnitude more than robotics. For travel to the Moon, Mars, etc., initial use could be made of serious autonomous robotics in situ resource utilization (ISRU) to produce human on body/planet needs to save hauling it there and enable check out/certification at on body/planet conditions. Once the robots have produced and proven out the equipage, then the humans could go at a much lower cost and increased safety. Because of the large number of major benefits, a sizable acceleration of the ongoing shift from physical air travel to digital reality is expected, especially for long haul. This would obviously impact the economic health of the air transport industry as a whole, from research through infrastructures/vehicle construction to utilization. However, there would still be a healthy air cargo industry in the nearer term, and perhaps not much additional impact upon the nascent, but evolving, UAS/ODM/UAM/PAV developments beyond the ongoing and longstanding shift to telecommuting/telework, as these are mostly short stage length with fewer tele-travel benefits overall than long haul PAX digital reality.

What is especially interesting concerning digital reality is that it is not constrained to reality. The prime part of our body is our brain; the rest provides support to keep the brain functioning. It literally is all in our heads. As demonstrated by many years with ever improving virtual worlds, augmented reality, video gaming, digital reality can be real, partially real, or unreal. Especially when using VR, the brain can perceive it as real. Going forward, it is possible to experience just about anything which can be conceived by either man or machine or their combination. At this juncture, the movie “The Matrix” may come to mind.

Increasing “Cyborgism” (Refs. 13, 14)

Humans have long utilized various devices/approaches to augment and/or repair their bodies. Among the earliest were false teeth, structural prostheses (e.g., wooden legs) and glasses. To this list were added hearing aids and toupees, and recently a collection of implants including cochlear implants for hearing, artificial retinas for seeing, artificial hearts for living, artificial limbs for moving/functioning. Currently, there are serious efforts to print internal human organs. An arena that will have massive impacts going forward involves brain chips, initially to fix brain issues but increasingly to augment brains. There are major efforts ongoing to develop superb computer-brain communications and interactions. The potential impacts of the latter are human changing:

- Greatly increases human capabilities, with potentially great disparities between humans depending upon the details of the individually installed and direct interactive capabilities and their availability/ cost.
- Rather than humans vs. the machines, we are merging
- As indicated, it is all in our heads and humans may decide that the god’s eye view and knowledge of the connectome/machine intelligence/knowledge/ data/”existence” is preferable to maintaining the rest of the wet electrochemistry physiology and humans could “upload” into the machines.

This latter possibility has moved from science fiction to serious research efforts. There are three major possibilities and their combinatorials with regard to evolution of the humans, ever more becoming cyborg-like, a bio-evolution enabled very long life with enhanced capabilities and uploading. Hans Moravec [ref. 15] suggested we would explore the stars as our “Mind Children,” (i.e., we will upload). Whither humans requires serious study. There are developments with regard to all three of these futures and others will probably arise. The first two futures are ongoing efforts and the third is under study. These are perhaps more near term than some think.

Of the three 20th century major governance approaches, Communism, Fascism, and Libertarianism, the latter, per Harari [ref. 16], is purportedly based upon serious economic growth that results in raising all boats. The several ongoing existential societal issues, including climate, ecosystem, machines taking the jobs, increasing wealth disparity, etc. have weakened the continual major growth libertarian mantra. As a result, there has been a shift toward nationalism and protectionism. Of concern is what could replace the growth mantra going forward. In the mid to long term timeframe, cyborgism and uploading would alter greatly the need for physical economic growth, as would the subsequently discussed DIY on steroids approach or enabling a shift to green growth. In the IT Age, wealth is increasingly generated by creating, inventing things versus exploitation of natural resources.

Serious DIY, High Tech Back To The Land Futures (Refs 6, 17)

Before the Industrial Revolution, there were few jobs per se; approximately 90% of the work force were farmers. Jobs, such as working for corporations and businesses are an artifact of the Industrial Revolution, which is over. We are now in the IT Age and heading rapidly into the Virtual Age. In the IT Age, as Robotics, AI, etc. are developing, the machines are increasingly more capable and cost less than humans for an increasing percentage of employment.

One solution space for this is a guaranteed annual income, funded by the value added provided by the machines. Another solution, which is also a solution for climate and the ecosystem degradation, is a Back To The Future approach, going back to the land, but this time employing the huge capabilities, efficiencies, and comforts afforded by the technology revolutions. There is some six acres per person available, and with the Bio Revolution engendered capabilities only a half-acre would be needed to grow food. As a result of the tremendous efficiency improvements and cost reductions for renewable energy and energy storage, an individual home site could produce its own energy, termed distributed generation. Water could be recycled and mulch piles utilized. With on-site printing, a family could manufacture much of what it needed. Tele-everything/digital reality as discussed herein, could provide tele-med, tele-ed, tele-travel, tele-shopping, tele-socialization, tele-commerce ETC, and families could become a part of the greatly expanding GIG economy. The rapidly evolving EVTOL air vehicles would provide very rapid physical travel and very long commutes as needed.

If a sizable portion of society chose to live this way, it would solve many of the existential and near existential issues facing us, including machines taking the jobs, food shortages, income disparities and the ecosystem and climate/energy issues. This approach/societal change was seriously tried in the 70’s, but without the vast changes, enablements from technology developments that have occurred since that time.

Rise of the Robots (Refs. 18 – 20)

The IT, nano and now AI and energetics technology revolutions have collectively enabled the development of superb robotics as a whole, which are still improving and moving from automatics to autonomy. For energetics, batteries are approaching, with the research on lithium - air, etc., chemical energy density. Going forward, batteries will, as it is efficacious, be augmented by energy harvesting or PV, which is now slated to approach 70% to 80% efficiency via two electrons per photon and utilization of more of the solar spectrum. In space, there is a new NASA nuclear battery, termed NTAC, which can provide up to 22 Kws/Kg of isotope with an alpha, Kgs/Kw, of order one to power robotics operations and just about everything else with regard to space faring. Robotic operations could, utilizing brute force machine ideation via systems evaluations at machine speeds of huge numbers of quasi random combinatorials, successfully work unknown unknowns and provide trusted autonomy operation. Robotic operations are both providing enhanced operational capability, greater/different than humans could provide and, including due to cost, increasingly replacing humans. Autonomous robotic operations on Mars (e.g., conducting ISRU utilizing the myriad and extensive resources on Mars) could produce what supplies are needed and check out at on-planet conditions, much of what humans on Mars would need before human arrival. This would provide considerable cost and safety benefits. The basic enabler for doubling the commercial aero market is autonomous robotic operation of both the UAS/PAV vehicles and the ATC system for many tens of millions of vehicles. This is a potential trillion dollar new Aero market.

Compared to human operations, the potential benefits of autonomous machines are many:

- Exclusion of human operator error. While machine errors exist in self-driving cars, for example, they are fewer than those committed by humans thus far.
- Reduced latency
- Autonomous machines are more durable and patient.
- Potentially-to-often more efficient and faster
- Longer duty cycles that are not limited by human attention spans and needs for sleep/nutrition, etc.
- Possibilities for size reductions. Working spaces don't have to be sized for humans and the conditions required to keep them healthy.
- Increased knowledge. For example, IBM's Watson machine using "Deep Learning" has proven successful because it knows far more than individual practitioners.
- Reduced cost, most system costs involve paying people. The machines are famously taking the jobs. As a major nascent example, self-driving trucks have been developed, and truck drivers are a major employment segment.
- New functionalities beyond those available from human capabilities. Machines can operate under conditions such as high radiation levels where humans cannot go safely.

The Bio Revolution (Refs. 21, 22)

The 1800s can be termed the century of the engineer, the 1900s the century of the physicist, and now the 2000s has been termed the century of the biologist. The Bio revolution, which has developed/is developing such as genomics, proteomics, synbio, Crisper, etc. is having major impacts upon society and the economy. Developing now is bioproduction, where manufacturing in some cases uses bioprocesses and bio functionalism, where in some cases what is produced has bio components. Genomically altered bio products are common for food, fodder, and other uses. As part of the evolution of humans, the bio revolution has enabled significant increases from year to year in human life expectancy. Going forward, there are potential opportunities via biologics to alter human capabilities including even possibly water breathing and designer progeny. Especially for space ISRU, there is biomining. Biomimetics has yielded biomaterials and bio has revolutionized agricultural productivity. The combination of IT and bio is enabling ever improved human brain-machine interaction/communication. Immune boosting, nano implants, and many other bio modalities are lengthening human lives from .3 years/year life extension to some projections approaching one year/year. Halophytes (i.e., salt plants) as discussed in the energetics section, are grown in deserts and wastelands using saline/seawater could literally, soon, and affordably solve land, water, food, and climate issues. Then there are pollution eating bio. and biologics to enable plants to take up atmospheric nitrogen, bioelectronics, bio cement, bio adhesives and, overall, major opportunities for sustainability.

Halophytes As a Solution to Land, Water, Food, Energy and Climate (Refs. 9, 23)

There are some 10,000 natural halophytes, which are plants that are tolerant to saline land and water. Many halophyte land plants will grow reasonably well using direct seawater (no desalinization needed), even before we introduce advanced genomics. These plants could produce nearly all that glycophytes (freshwater plants) now produce.

The immense advantages of switching to halophytes include:

- Saline-tolerant plant biomass using what we have a surfeit of (and what could be our last major play regarding the ecosystem): wastelands, deserts (44% of the land area), and saline aquifers/seawater (97% of the planet's water resources).
- Seawater contains some 80% of the nutrients needed to grow plants, and researchers are developing new techniques for plants to extract nitrogen from the air, thus requiring little fertilizer.
- Advanced technology is not required and cultivation uses inexpensive land and water, inexpensive solar PV could be used to pump water, the economics are reasonable. The shift to halophytes could be accomplished in relatively short order.
- Halophyte cultivation for food would free up the 70 percent or more of the freshwater we use for conventional glycophyte agriculture, and which we are now running out of, for direct human use, thus solving both water and food problems.
- Cultivation of halophyte biomass would similarly obviate the use of arable land and freshwater for biofuels and provide petrochemical feedstocks for plastics and other industrial products. It is literally “green energy” and chemicals.

- Halophytes sequester up to 18% of their carbon dioxide uptake in their roots, removing CO_2 from the atmosphere. Large scale Halophyte cultivation on deserts and wastelands would produce major reductions in atmospheric CO_2 levels.
- Seawater contains trace elements essential to healthy human physiology, which we have largely depleted from arable land due to overuse.

Cyanobacteria, seaweed, and algae represent another class of halophytes with potential for aquacultural development. Several of these produce excellent oils and protein and are far more productive than land-based plants. Through genetic engineering, aquacultural halophytes may have enormous productivity.
The continent-sized nutrient stream that is the Mississippi River outflow into the Gulf of Mexico, which is now causing overly rich anoxic conditions, could possibly be used to foster aquaculture, thus reducing pumping costs, land taxes, and other costs. The worldwide capacity for aquaculture to replace freshwater use in producing food and biofuels—and provide sustenance to a much larger future human population—is massive.

Overall, halophyte cultivation and development could address our interrelated land, water, food, energy, and climate problems. This approach does not solve income disparity, the machines taking the jobs, or the intelligent machines problems. However, it would provide society some breathing room and push the classical Malthus issue of population outgrowing resources downstream by perhaps a century or more, alleviating many societal issues in a synergistic fashion.

The Renewable Energy/Storage Revolution, Solving Climate (Refs. 24 – 26)

Climate change, primarily a result of anthropogenic CO_2 emissions, is becoming serious to deadly, with many worldwide adverse manifestations. The solution approaches include serious energy conservation, now ongoing with buildings that generate vice use externally generated energy etc. and reducing both extant and fossil fuel generated CO_2. As already discussed, greening the planet via growing halophytes on deserts and wastelands would, due to root sequestration, pull CO_2 out of the air. The remaining major climate approach is reducing fossil fuel generated CO_2 emission from coal, gas, and petroleum. A substantial percentage of the latter is used for petrochemical feedstock for plastics, and as stated herein, the huge amounts of biomass from serious halophyte production could replace petroleum for that purpose. There has been, since the Arab oil embargo of the 1970's, extensive/accelerated research in renewable energy, including PV, wind, geothermal, hydro, biomass, and solar thermal with a combined capacity of some 16,000 exojoules. Our current fossil carbon fuels generation, the energy we use, is approximately 500 exojoules, far less than what renewables are capable of producing. There are also several large capacity renewable energy sources not yet tapped, including heat exchangers in the gulf stream and high altitude wind.

The research over the past decades has now resulted in renewables that are below cost parity and less expensive than fossil carbon generation, sparking a major uptick in their utilization. That in turn has resulted in nuclear plants not being cost competitive and some closing as a result. Coal generation has plummeted for the same reason. PV and storage costs have reduced some 85% in the last eight years and PV plus storage are now half the cost of a gas peaker plant. Renewables now account for 65% of new generation, 30% of world electricity generation and there are projections for 80% in one to two decades as costs continue to decrease. With PV selling at 1.7 cents a Kwh and still dropping (versus fossil fuel costs in the 5 cents range), some are starting to posit electrical energy too cheap to meter going forward. Also, the PV efficiency, via two electrons per photon and more of the spectrum is projected to greatly increase into the 70% plus range, making PV interesting for external film application to cars, planes, ships, as well as homes, the latter termed distributed generation.

With the excellent outlook for inexpensive green electricity, and the progress in greater than Li-ion battery storage energy density now 2X to 3X, there are now serious ongoing efforts to convert transportation to electrics. This would greatly reduce even further the use of heavy transportation fuels such as petroleum. This is for all transportation whether via land, sea, air, or space. Also, with inexpensive green electricity available many of the industrial processes could convert processes now utilizing fossil fuels to green electrics. So, renewable electricity generation/storage reduces not only CO_2 due to electrical generation, it would also reduce most of the other uses of fossil fuels as well. Also, cheap green electricity would enable such as desalinization, ocean resource extraction and other processes that were previously too expensive energy wise. With regard to aerospace, the outlook via renewables is that electric, emission less aircraft would use much less energy due to improved efficiencies (e.g., electric motors are almost twice as efficient).

Printing Manufacture, Advanced Materials (Refs. 27, 28)

Rather than cutting we are increasingly adding for manufacture. This process is termed printing. This alternative manufacturing process has developed rapidly over the past decade and is now applied across many industries and product functionalities, including rocket engines. Printing results in far less waste, is increasingly autonomous, and less expensive than industrial age manufacture. An initial concern with printing was the resulting material microstructure, which dictates material/product performance. Recent efforts in applying printing at the nano scale has resulted in improved microstructures with less dislocation and grain boundary problems in metals. It’s also shown an improvement in some material properties by a factor of five, with another factor of five projected. Printing can also be used to craft material substructures such as tetrahedrons, termed architectural materials, that are both strong and light.

Another not yet widely explored approach for improved materials is simultaneous-to-sequential materials processing. There are a large number of material processing approaches that when combined, usually obtain different resulting properties. Sometimes the different properties are better, sometimes they are different. This is thus far exploratory physical/chemistry science and engineering. If quantum computing develops well, such combinatorials could be explored computationally, probably much more rapidly and at less cost. With some 18 ways to process materials, there are some 18! combinations to explore. For morphing surfaces (e.g., flow control/flight optimization) there are shape memory materials, nano material actuators and piezoelectrics, among others.

Overall, Combinational Effects Of Disruptive Technologies on Society and Aerospace Going Forward

Society:

- Long lived humans, increasingly "cyborged"/composed of increasingly artificial content, superb brain/machine interactions/communications/augmented brains
- Increased virtual/tele-everything, less physical travel, massive vulnerabilities to cyber, jamming, EMP
- Autonomous robotics for nearly all functionalities/purposes
- AI near/at/beyond (?) human, machine ideation/invention
- Quantum computing, mod-sim vice physical experiments and design, measurement of initial, boundary conditions required or computed
- Global sensor grid, trillions of multiphysics networked sensors
- Global brain
- Green, inexpensive renewable energy and storage, extensive electrification and decarbonization
- At home printing manufacture, distributed energy generation, food production, recycling (e.g., water)
- Nano printed, superb microstructure and architectural sub element materials
- Food and water availability from halophytes grown in deserts/wastelands using saline/seawater
- Wealth creation via invention vice exploitation of natural resources
- After creating a second intelligent species (e.g., autonomous AI robotics), humans are developing humanity 2.0 (guaranteed annual income, virtual/tele - living, DIY/high tech back to the land, uploads, anti-aging/ long lived, enhanced cyborgism, etc.)

Impacts upon the extant major to existential societal issues:

- Guaranteed annual income and DIY/high tech back to the land addresses <u>Income Disparities</u>
- DIY/high tech back to the land addresses <u>Machines Taking the Jobs</u>
- Halophytes and renewable energy and DIY/high tech back to the land address <u>Climate and Ecosystem</u>
- Distributed electrical generation addresses <u>Solar Storms</u>
- Halophytes address <u>Food and Water</u>
- Not addressed – <u>Population and Super Intelligent Machines</u>

Resultant Major Aerospace Developments Going Forward

- Electric aircraft via 5X materials, 2x aero performance, and 5X plus batteries
- Autonomous Fly/drive EVTOL, replaces autos, auto infrastructures, and much of scheduled commercial airline service, new ~ $1 T/ yr. aero market
- Tele/virtual travel reduces long haul physical air travel
- Autonomous ATC system for tens of millions of flying vehicles
- Superb virtual presence space travel/exploration via autonomous AI space robotics/ digital reality
- Air transport increasingly electric
- Ever more mod-sim, less physical experiments
- Inexpensive space access via reusability and autonomous robotics manufacture and operations
- Development of a major, beyond GEO, deep space economy for space vacations, manufacturing, resource extraction - via inexpensive space access and autonomous robotics
- Mars colonization via cheap space access, autonomous robotics, exploitation of the huge Martian resources (e.g., ISRU), humans evolving for Martian gravity
- Clean-up/repurpose in space/remanufacture space debris via solar or nuclear battery powered tethers, including in due course the International Space Station (ISS)
- Miniaturized sats and UAS as platforms for miniaturized instruments to determine detailed physics of cloud microphysics/aerosols, the greatest current unknown in climate projections
- Extensive R&D to understand and possibly exploit for interstellar transportation the many unsolved problems in physics including dark matter, dark energy, the 120 orders of magnitude difference between quantum predictions and the observed cosmological constant, the physics responsible for the measured greater than 10,000 times light speed action of quantum entanglement, what happened to the anti-matter, quantum gravity, among many others. Such very revolutionary understanding might inform transportation approaches for interstellar travel.

Concluding Remarks

Major societal existential change agents going forward include climate and associated sea level rise, changes in rainfall, storms, ongoing ecosystem degeneration, increasing income disparities, the AI/ digitization related changes and, recently, pandemics. These are and will drive major societal changes, many enabled by disruptive technologies which will include movements away from low shorelines, increased tele-everything and digital reality, and prospective deurbanization and increasing shifts back to the land. This latter shift would be to a way of life where, on a small holding, an individual could produce their food, energy, much of their equipage and be economically independent. Such a DIY way of living largely solves climate, ecosystem issues and economic disparities while massively altering the current economic order and the reliance on continual growth for econometrics on a planet with fixed resources, aka sustainability.

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