Sustainability Writ Large:

A Perspective on Sustainability, Its Impact and Implications

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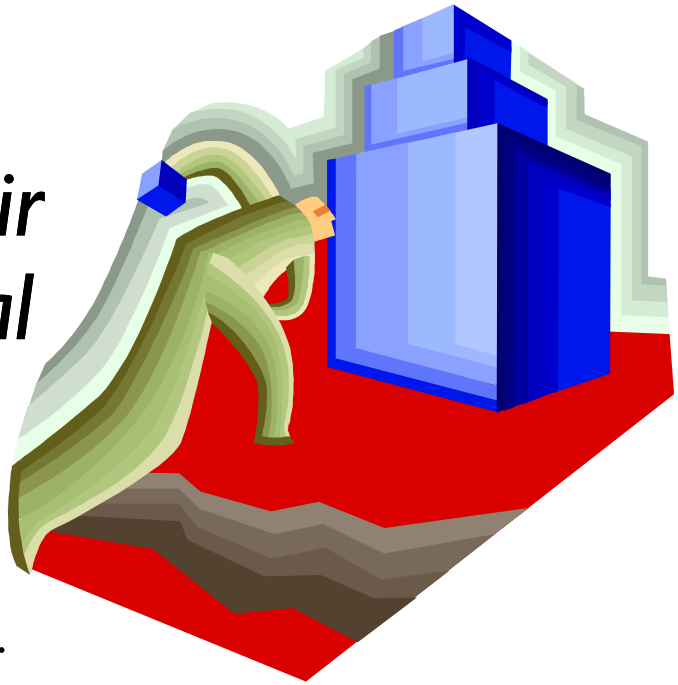
Verdant ELECTRONICS

Origins of Sustainability

- The Seventh Generation Philosophy – 1600s?
  - Centuries old Native American mandate that tribal decision makers consider the effects of their actions and decisions for descendants seven generations into the future. Acknowledgement that everything done today has consequences for something and someone else both now and in the future because of the interconnectedness of everything on the planet.
- United Nations' Brundtland Commission -1987
  - "Sustainable Development is development that meets needs of the present without compromising the ability of future generations to meet their own needs"
- World Summit on Social Development - 2004
  - Triple Bottom Line of Sustainable Development…
  - Economic development, social development, environmental protection

Industrial Ecology

Industrial ecology is the multidisciplinary study of industrial systems and economic activities, and their links to fundamental natural systems.



B. R. Allenby, *Industrial Ecology: Policy Framework and Implementation*, Prentice Hall, Englewood Cliffs, NJ (1999).

Sustainability Drivers

- **Top business drivers for sustainability**
  - Customer demand
  - Competitive advantage
  - Need to comply with legislation/standards
- **Social drivers for sustainability**
  - Public opinion
  - Corporate values and policies
  - Media spotlight (e.g. sustainability rankings)

Corporate Touchstones to Addressing Sustainability

- Management commitment
- Management Systems
- Stakeholder involvement
- Best practices identification
- Triple Bottom Line cornerstones
- Supply chain buy in and involvement
- Measurement and Analysis (e.g. LCA)
- "On the record" communications
- Inculcation of the workforce
- Innovation and acceptance of change

Principles of Sustainable Production

Products are safe and ecologically sound throughout life cycle

- designed to be durable, repairable, readily recycled, compostable, or easily biodegradable;
- produced and packaged using the minimal amount of material and energy possible.

Processes are designed and operated such that:

- wastes and ecologically incompatible byproducts are reduced, eliminated or recycled on-site;
- substances or physical agents and conditions that present hazards to human health or the environment are eliminated;
- energy and materials are conserved, and the forms of energy and materials used are most appropriate for the desired ends;
- work spaces are designed to minimize or eliminate chemical, ergonomic and physical hazard.

Source: Lowell Center for Sustainable Production

Sustainability/Reliability Nexus

- To hold to the ideals of sustainable manufacturing, the electronics industry must make products that are be robust enough that they can be passed along to future users with no concern about longer term reliability.
- In Japan and elsewhere, the manufacturing community has rallied around the idea that to build sustainable products one only need consider "Three Rs"… Reduce, (materials and energy), Reuse and Recycle.
- Reliability should be added to that list as reliability and sustainability are really intrinsically linked.

Reliability is Defined as:

… the measure of a product's ability to:

perform a specific function or service

in a specified use environment

for a specified amount of time without unscheduled interruption

Reliability is commonly reported in terms such as mean time to failure.

However it was suggested by one observer that reliability may perhaps be best measured not on the return of product but by the return of the customer…

Reliability is key to customer trust and retention

Changing Views on Reliability

- Reliability expectations vary for different types of products depending on application.
- However the importance of reliability has been fading, especially for consumer products due to faster products cycles
- The concept of application specific reliability should be a concern to manufacturer and consumer alike
- Electronic products are rapidly becoming much like seasonal fashion statements
- Is the electronics industry headed in the right direction?

Reliability and Economics

Origins of Planned Obsolescence

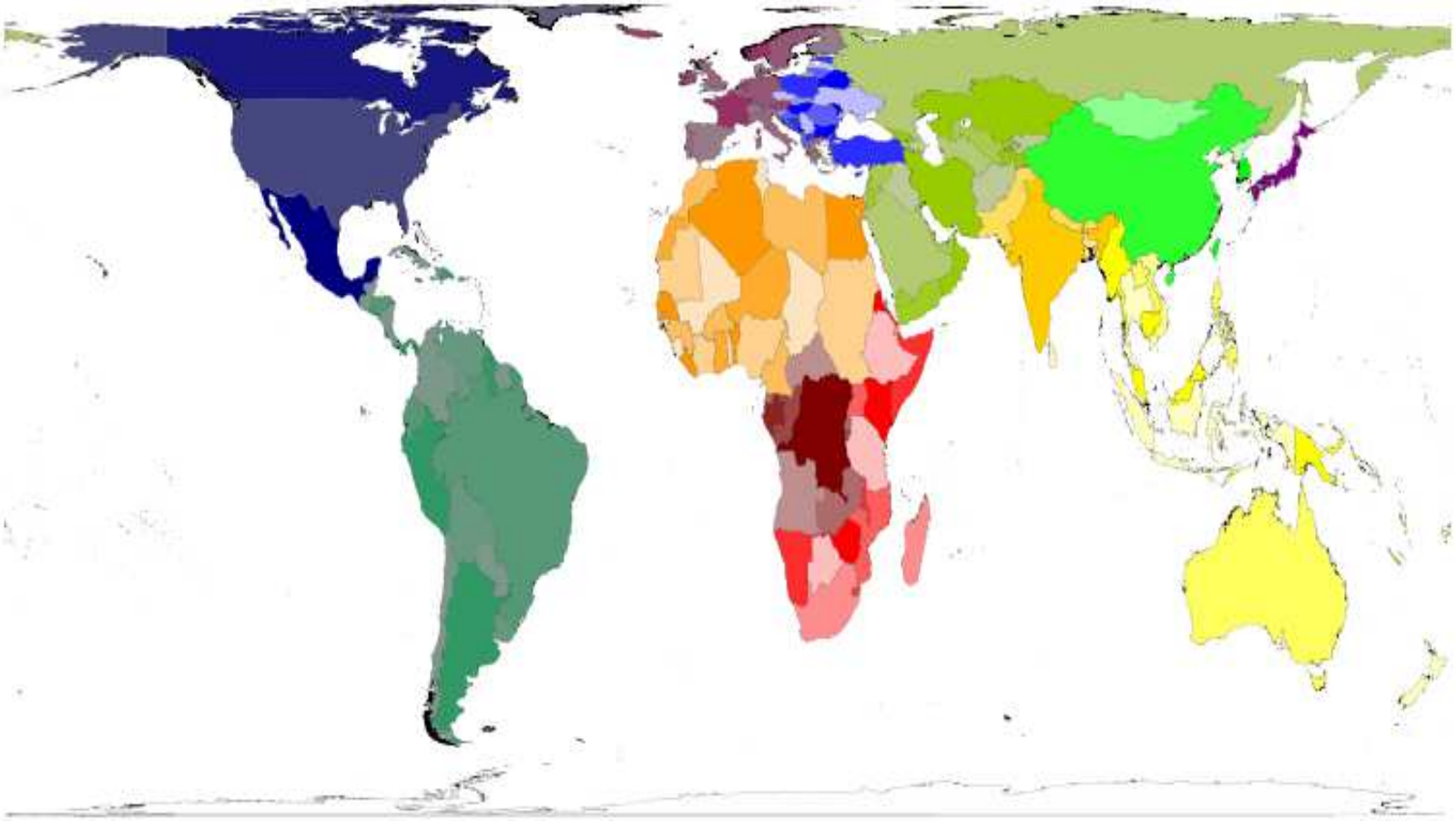
- Concept dated to 1932 with the publication of Bernard London's pamphlet titled *"Ending the Depression through Planned Obsolescence"*.
- The fundamental idea was to create products that became obsolete or ceased to function after a certain period of time or amount of use in a way that is planned or designed for by the manufacturer
- The concept holds sway still today but there have been subtle changes…
- Advertising influences emotions and confuses wants and needs

Planning for Failure

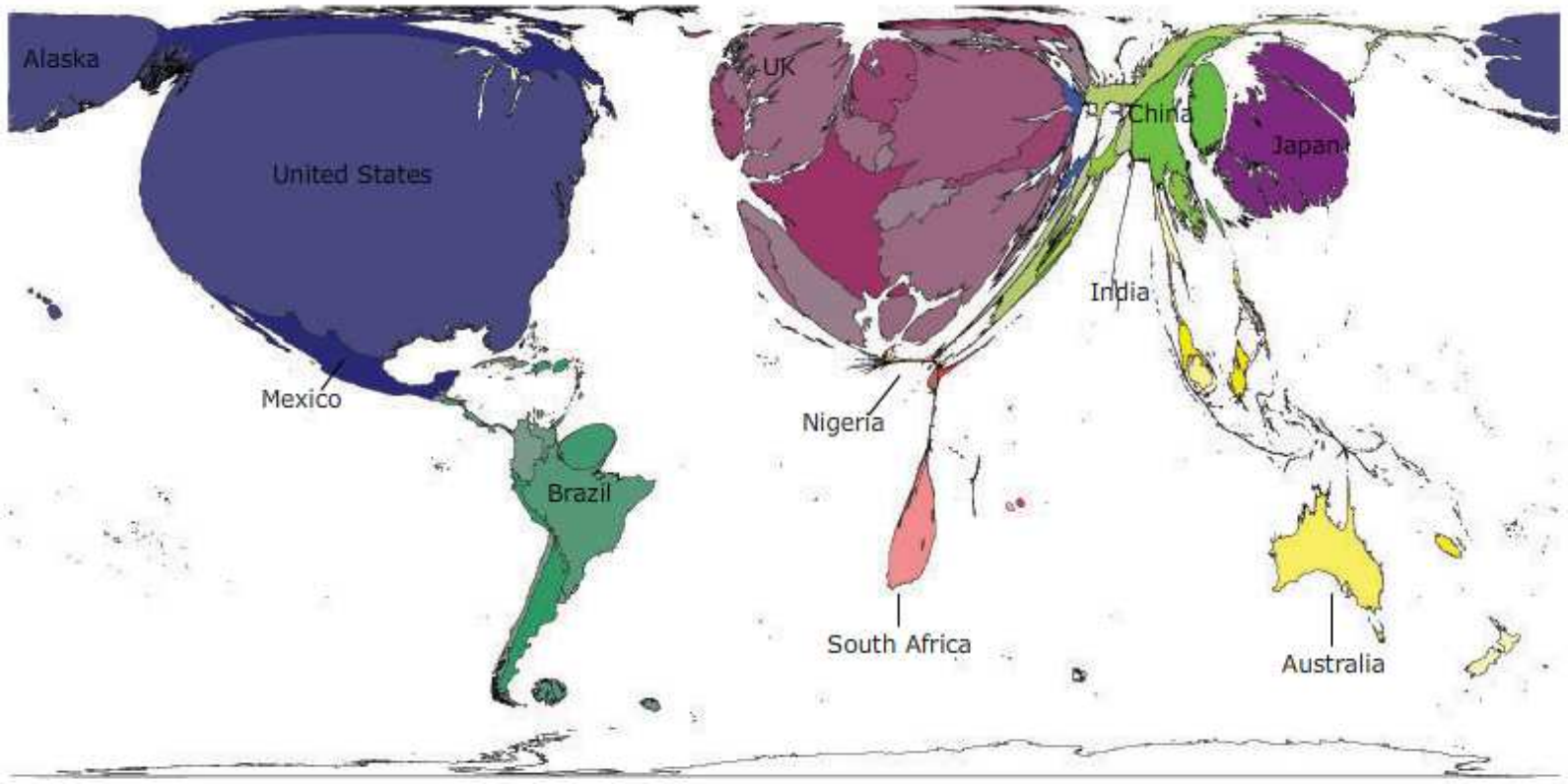
- For planned obsolescence to work, some self-destructive mechanisms must be integrated (implicitly if not explicitly) into the manufacturing systems. One is a reduced concern about reliability.
- "Brave New World" by Aldus Huxley - Here and Now?
- There is another negative aspect to accelerating the rate of change in product cycles…

  It is simply not sustainable if all of the world's peoples are to be served and benefit from electronic products nor it is environmentally responsible

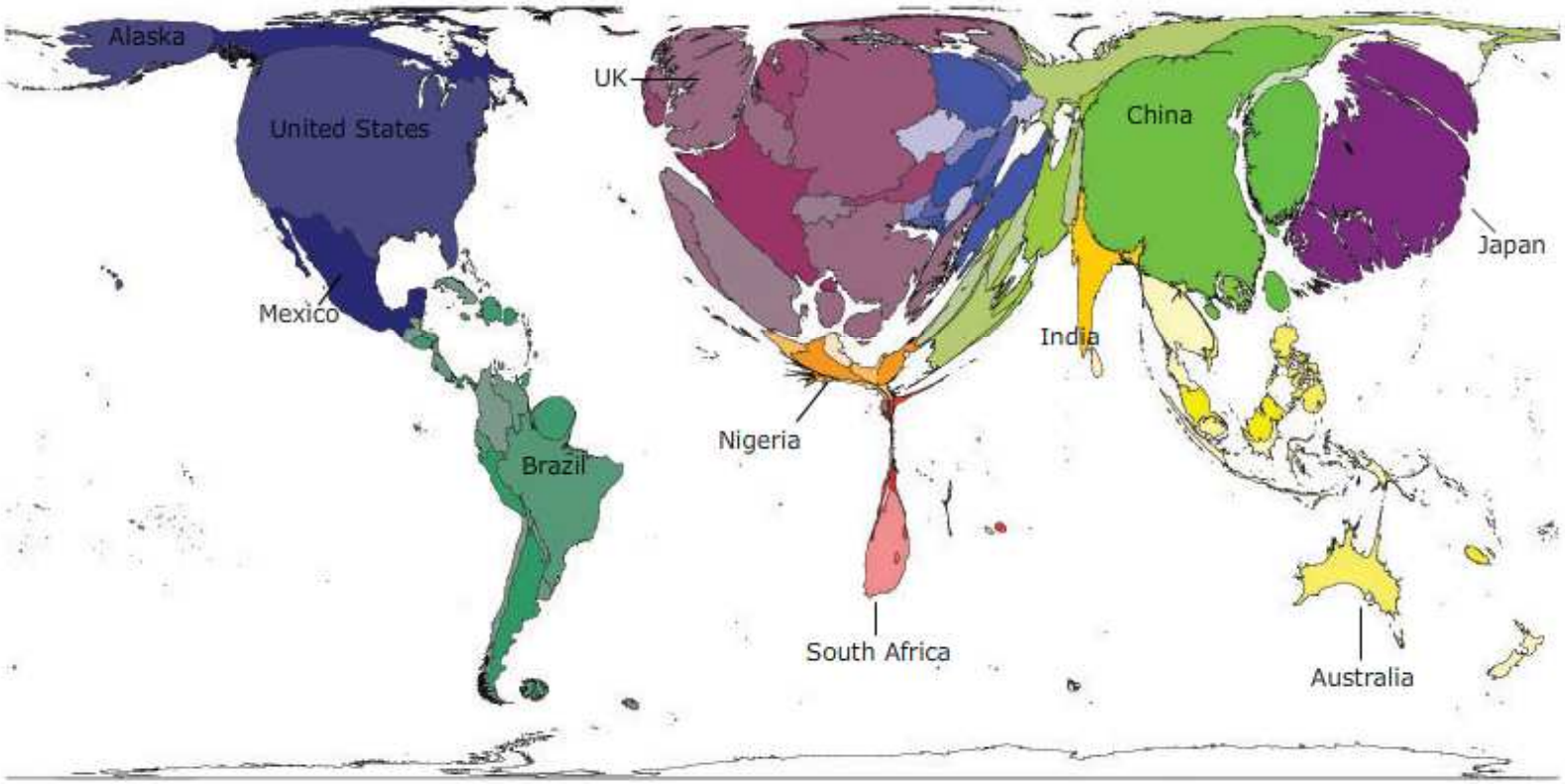
World Geo-Political Map



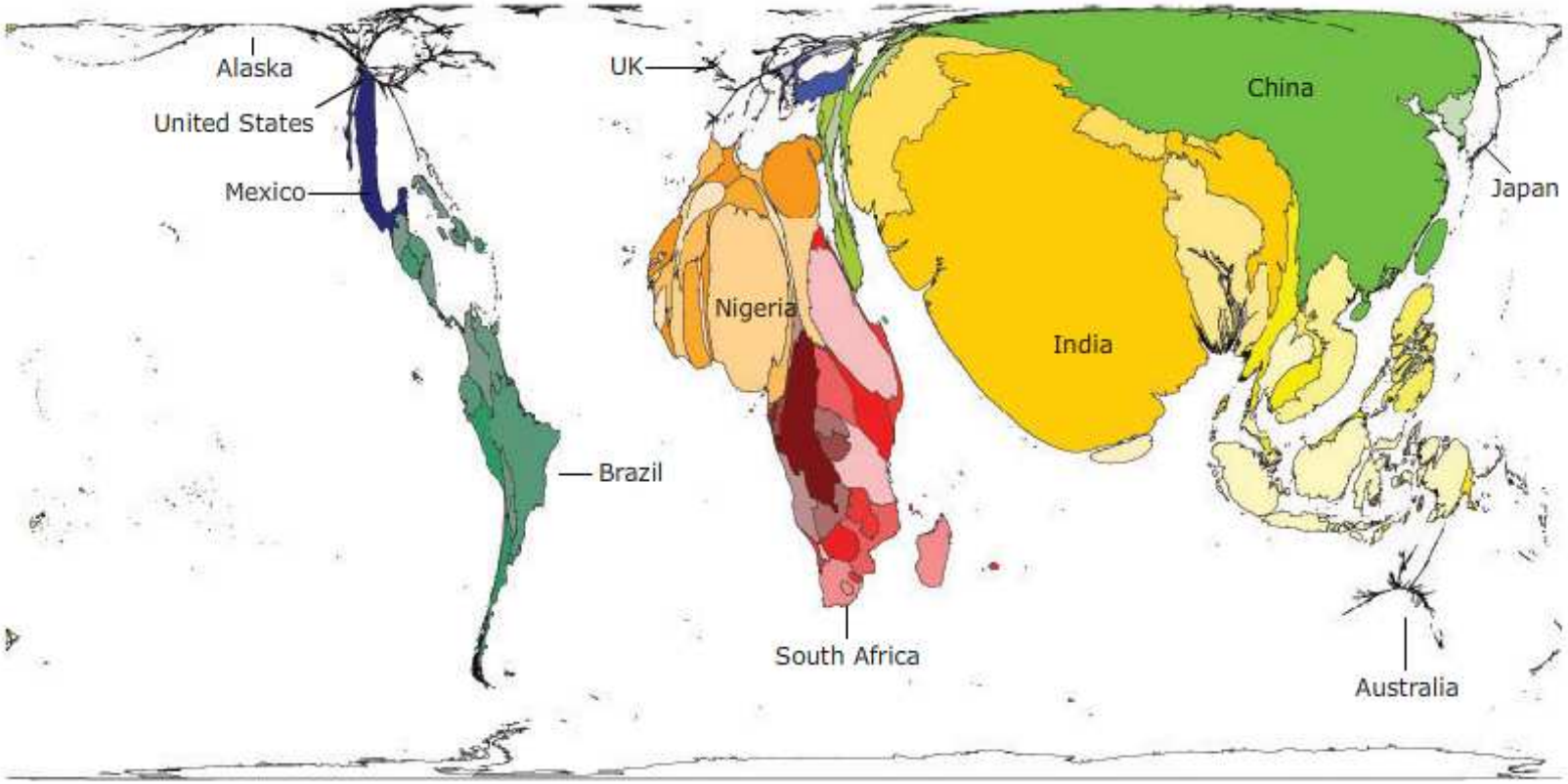
Individual Purchasing Power $100 to $200 per day



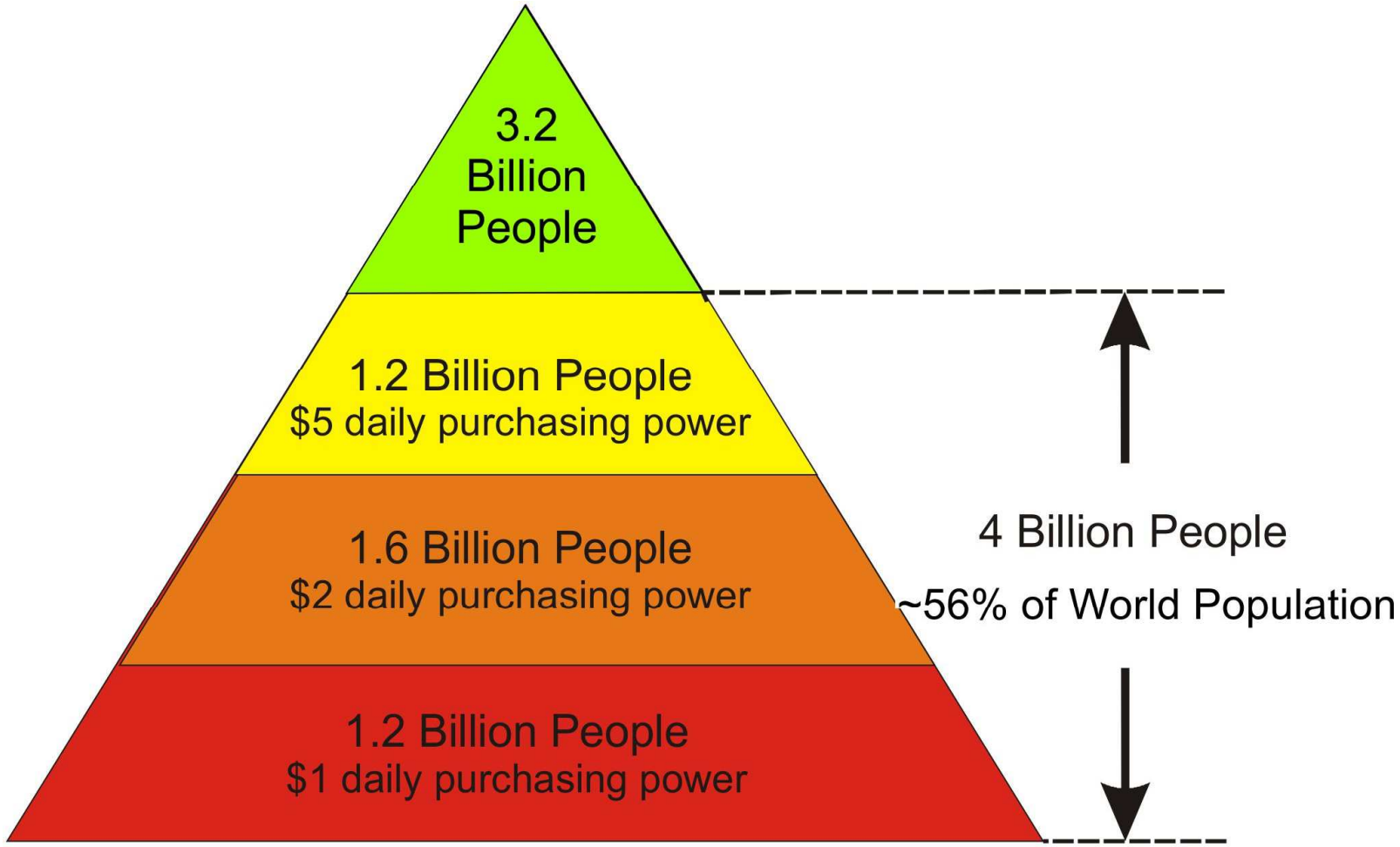
Individual Purchasing Power
$20 to $50 per day



Individual Purchasing Power
Less than $2 per day



More Reliable Products are Required to Meet the Needs of a Growing Population

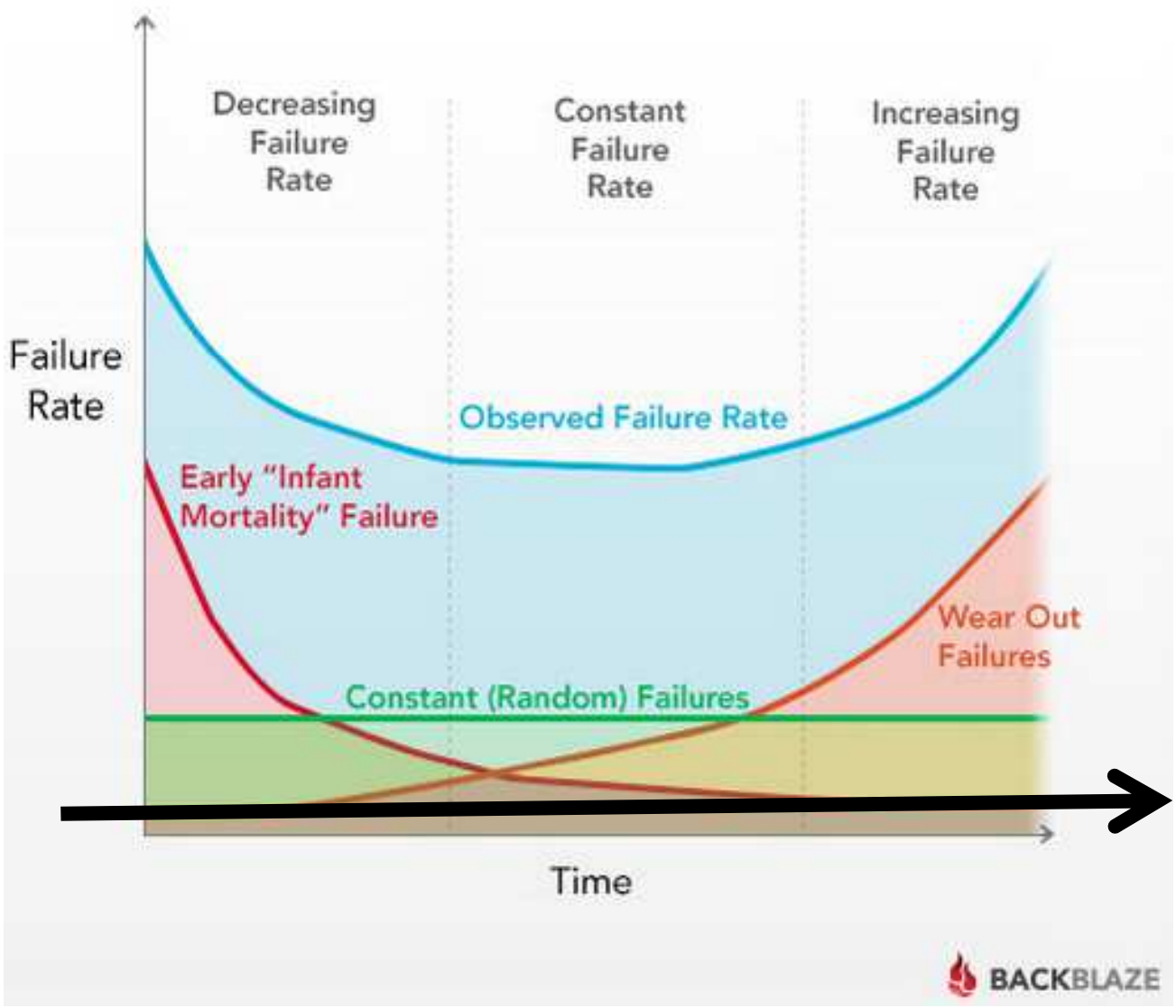


Low income = Lower education = Fewer opportunities and a higher birthrate

Electronics Slipping Reputation

- Warranty provider, Square Trade published a report titled: "*1 in 3 Laptops Fail Within 3 Years*"
- The report noted that a full two-thirds of these failures (20.4% of all product built) were the result of hardware malfunctions.
- The other third (10.6%) were from accidental damage
- The report also noted that the increasingly popular netbooks are projected to have a 20% higher failure rate from hardware malfunctions than more expensive laptop computers.
- This should be a wake up call to both electronic manufacturers and electronic consumers alike

General Failure Rates



Failure Rates…
Are They Good Enough?

Economics of Early Failure

- Early failures result in higher warranty costs to the manufacturer and the potential for product recalls, the cost of which can run into tens of millions of dollars
- Those millions in losses could potentially be multiplied many times over as every manufacturer faces the same risk when products do not perform to promised levels.
- In short, poor reliability is very costly to individual companies, the world's peoples & the environment

Reliability and The Environment

"Green" Legislation Impact

"The road to hell is paved with good intentions"
~ Proverb ~

- Lead free solder is impacting reliability
  - Moisture sensitivity increase
  - Thermal damage to components and boards
  - Shock and Vibration
  - Tin whiskers
- Net effect?
  - Reduced product reliability at increased cost
  - Overall negative effect on the environment

Reliability of Electronic Elements

Some Known Weaknesses

Capacitors

- Ceramic Capacitors (dielectric breakdown) are also fragile
- Electrolytic Capacitors (electrolyte evap., dielectric dissolution)

Resistors

- Must be properly de-rated for use in application to assure reliability

Integrated Circuits

- Future generation designs with few nm features will be at risk

Relays (and other electromechanical components)

- Limited ability to models wear out at present

Connectors

- Must be properly matched to design, properly specified and placed

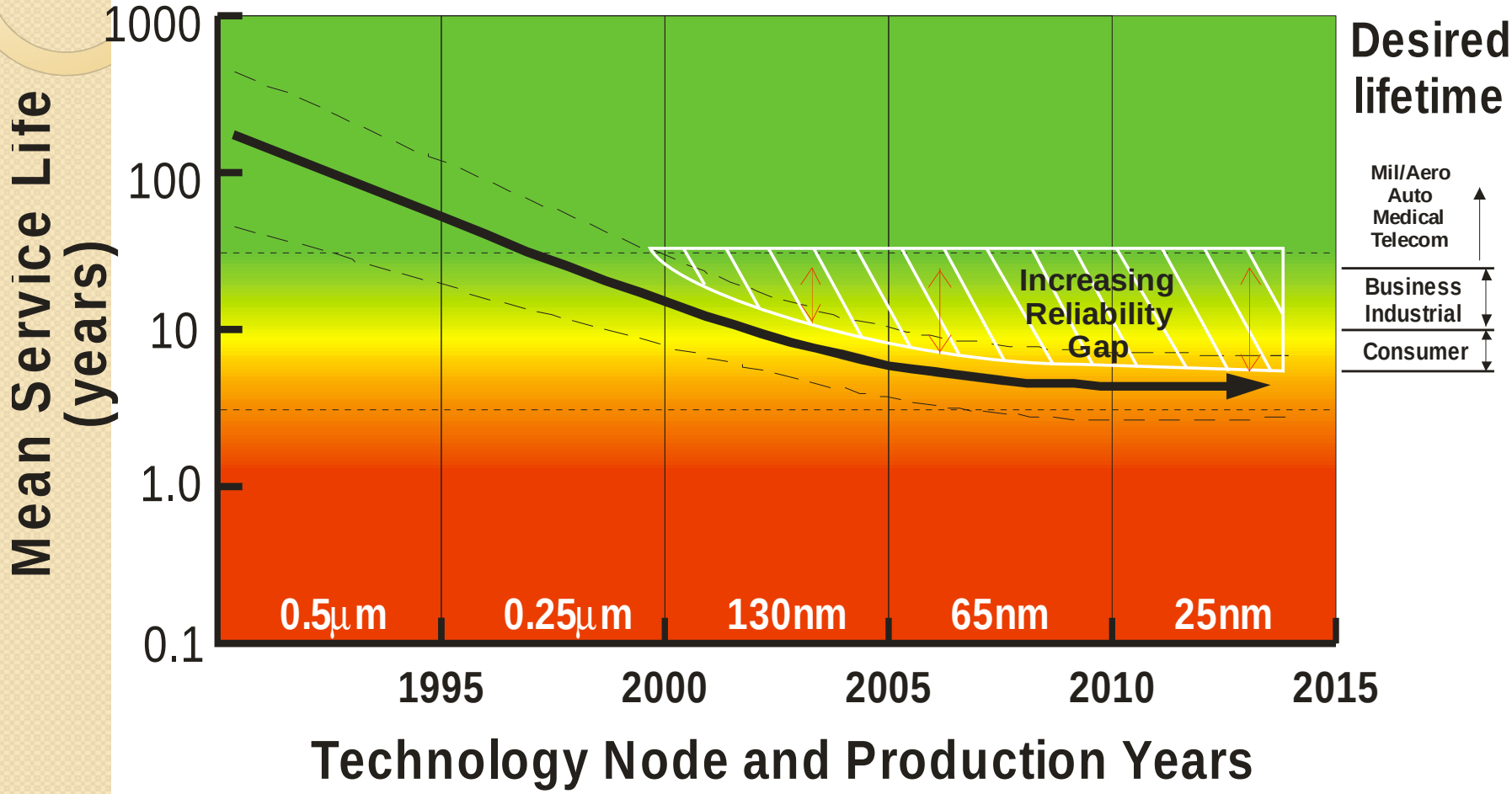
Solder Joints

- Most electronic failures occur at interconnections
- Solder creep, fatigue and shock resistance are concerns
- Tin whiskers are a wild card

Looming Concerns About ICs

- Solder is not the only concern in the increase being seen in early electronic failures
- It has pointed out that the semiconductor industry, which is driven largely by Moore's Law, continues to pursue new ever finer feature nodes, seemingly oblivious to the impact of such efforts on long term reliability
- We are facing a growing gap between customer desires for long life and performance reality
- Can sustainability objectives be better served by going back?

The Growing Reliability Gap



Modified after C.Hillman

Reliability and Design

Most Reliability Problems Begin at Design

- **Many important questions must be asked upfront**
  - Does design match up with capabilities of the selected manufacturer?
  - Are trace and space within current standard manufacturing limits?
  - What laminate material will be used?
  - Is design symmetrical from side to side? How many layers?
  - What type of plated interconnections will be used?
  - How thick is board and what assembly methods are anticipated?
  - What assembly materials and equipment will be used?
  - What types of components will be used and what is their structure?
  - Is the component spacing appropriate?
  - What is the maximum size component?
  - Will stacking of components be employed?
  - Are components kept distant from prospective points of flexure?
  - What is/are the moisture sensitivity level (MSL) of the components?
  - Will second operation assembly be required?

Aluminum Substrates for Electronics …A more sustainable alternative?

FR4 – Foundation of Electronics

- Resin glass composite laminates have been the PCB industry's "go to" material for decades
- It has its drawbacks, however
  - Temperature limits of resins, price coupled to oil, dimensional instability, warpage concerns, variable CTE in XY and Z based on resin and glass type and construction, requires flame retardants

Aluminum: A Feature Rich and More Sustainable Alternative Substrate

Aluminum has **many attractive attributes** which make it an appealing circuit substrate alternative…

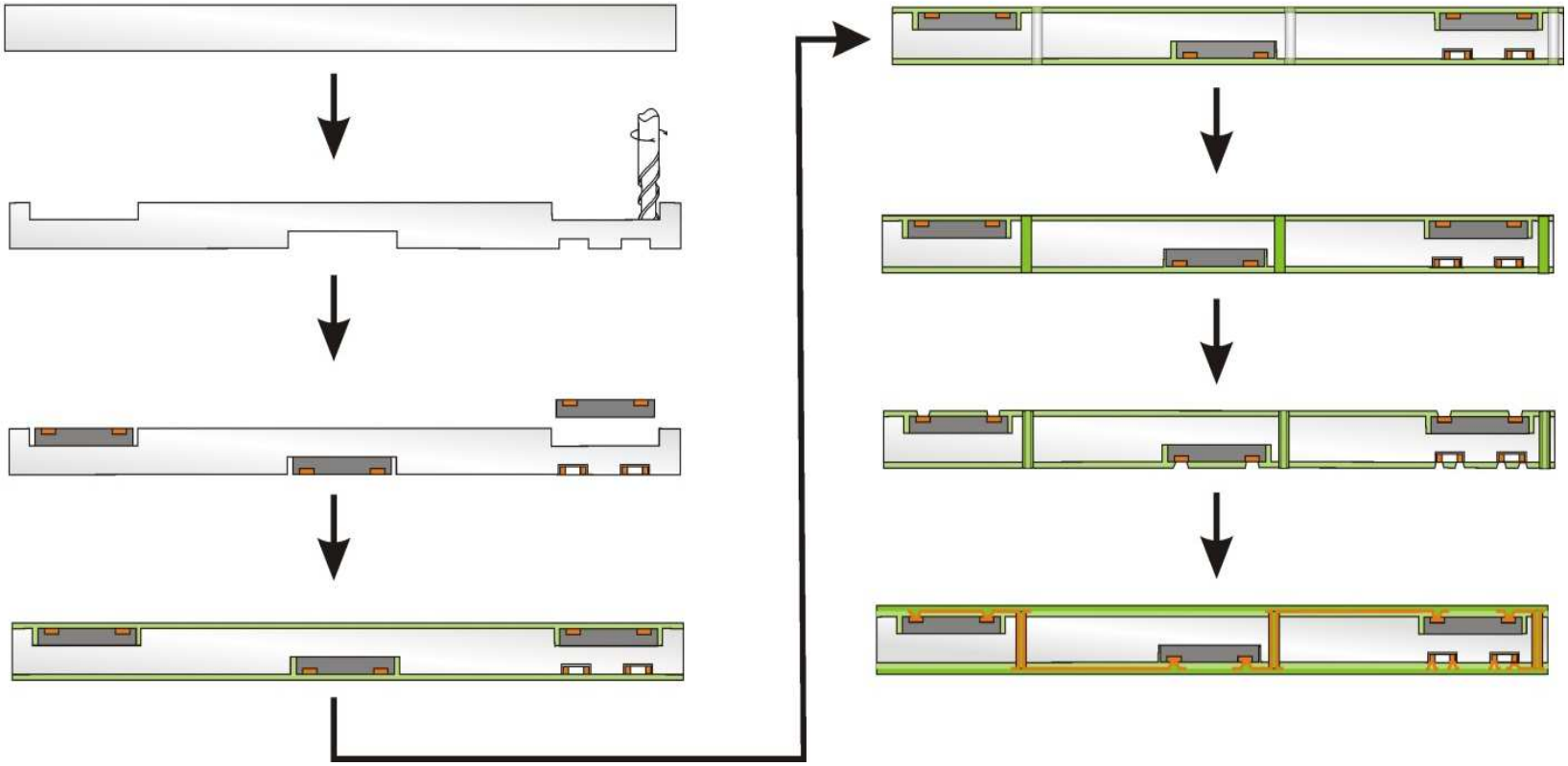
Aluminum is:

- **Abundant**: 3rd most common element (8.3 % of Earth's crust)
- **Nontoxic**/Environmentally friendly
- **Low cost**: $2.00/kg, $0.98/lb, $.015/mil/sq.ft.
- **Good thermal conductor** (~200 W/mK)
- **Relatively light we**ight (2.8g/cc vs 1.85 for FR4)
- **Dimensionally stable**
- **Good CTE** that approximates copper (22 vs 18 ppm/C)
- **Easily processed** (machined, punched, chemically milled)
- **Can be Anodized** to form an alumina (Al_2O_3) surface layer
- **Electrophoretically coatable** with epoxies or enamels
- **And it is a readily recyclable metal**

Why The Delay?

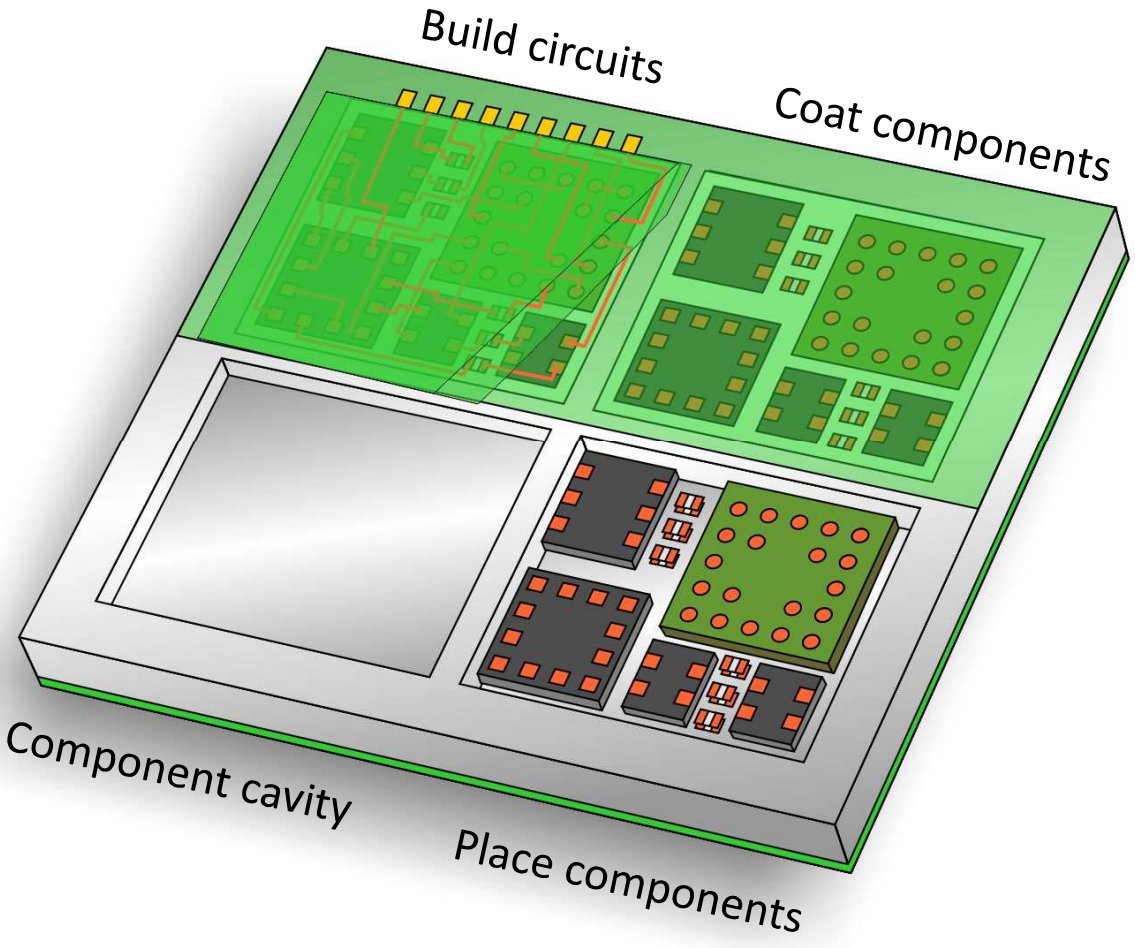
- Aluminum has be used in only a relatively few applications for a few compelling reasons, most notably is its high thermal conductivity which makes soldering difficult in the best of cases and nearly impossible in others.
- Good thermal conductivity increases the risk of the assembler forming cold joints on the one extreme and thermally damaging components at the other if dwells are excessive.
- Thus with some notable exceptions, such as for LEDs most designers have determined it is easier to use traditional laminates and then solve the thermal management issues associated with the assembly upon completion.
- There is however a way to employ aluminum if one is willing to think differently about the process of assembly, specifically by reversing the process and instead of placing components on circuit boards, building circuits on component boards…

Aluminum Process Example



Patented

Aluminum Substrate Structure



Summary

- Buckminster Fuller observed that "We are all astronauts" and that we are riding on "Spaceship Earth" It is an important reminder
- Everyone here today is blessed and those blessings should be shared with others who will never see the inside of a building like this.
- Waste is the enemy, not the friend of progress. Sustainable manufacturing and systems must defeat wastefulness.
- Making more reliable products should result in significant cost and energy savings and equally important, more sustainable and more environmentally responsible products to help address the needs of the four billion people at the bottom of the world's economic pyramid.

Global Reporting Initiative

G4 Sustainability Reporting Guidelines

TABLE 1: CATEGORIES AND ASPECTS IN THE GUIDELINES

Category	Economic		Environmental
Aspects [III]	• Economic Performance • Market Presence • Indirect Economic Impacts • Procurement Practices		• Materials • Energy • Water • Biodiversity • Emissions • Effluents and Waste • Products and Services • Compliance • Transport • Overall • Supplier Environmental Assessment • Environmental Grievance Mechanisms

Category	Social			
Sub-Categories	Labor Practices and Decent Work	Human Rights	Society	Product Responsibility
Aspects [III]	• Employment • Labor/Management Relations • Occupational Health and Safety • Training and Education • Diversity and Equal Opportunity • Equal Remuneration for Women and Men • Supplier Assessment for Labor Practices • Labor Practices Grievance Mechanisms	• Investment • Non-discrimination • Freedom of Association and Collective Bargaining • Child Labor • Forced or Compulsory Labor • Security Practices • Indigenous Rights • Assessment • Supplier Human Rights Assessment • Human Rights Grievance Mechanisms	• Local Communities • Anti-corruption • Public Policy • Anti-competitive Behavior • Compliance • Supplier Assessment for Impacts on Society • Grievance Mechanisms for Impacts on Society	• Customer Health and Safety • Product and Service Labeling • Marketing Communications • Customer Privacy • Compliance

Thank you