Technology is all about Systems

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The Technology Systems Methodology is a powerful tool to understand value creation: essentially the application of know-how to integrate more basic resources:

Inputs + Know-How = Value-Added Outputs (i.e. Technology Systems)

At the product level[1], *technology systems* are built from four kinds of inputs: (1) the major device, (2) supporting subsystems, (3) components & materials, and (4) design. An example is the airplane (below).

Technology Systems Integrate Four Kinds of Inputs (Example: The Airplane)

(1) **Major Device**: the heart of system functionality (the wing, for lift).
(2) **Supporting Subsystems**: help the major device or the user (e.g. flight instruments for piloting; and flaps, to help generate lift at low speed).
(3) **Components & Materials**: the nuts and bolts of value creation (e.g. wing struts & aluminum).
(4) **Design**: the most effective way of configuring system resources to achieve desired performance.

The *major device* is the wing; it makes flight possible by generating lift as air flows over it. A *subsystem* is the engine: it keeps air flowing over the wing. Components & materials are lower level inputs from which the major device and its subsystems are constructed. For example, the wings of early aircraft were built from wooden spars and ribs, covered with canvas, lacquered to make it airtight and weatherproof.

Design is the key; it continually integrates advances in the major device, subsystems, and components & materials to improve system performance. For example, retractable landing gear made aircraft faster. The biplane (above) dominated early aircraft design; two wings offered the best compromise of strength, weight, and performance consistent with the era's engines, airframe materials, and construction techniques.

Design is driven by applications: the airplane was first used for aerial reconnaissance in World War I. It rapidly became a fighter, mounting machine guns to shoot down opposing reconnaissance planes. And in a fight, speed became an important performance objective. Below, the World Aircraft Speed Record traces how fighter speed increased in a highly regular, recurring pattern: *The S-Curve*.

[1] At the level of industries, the technology systems model frames inputs differently (see "Economic Development is a Team Sport").

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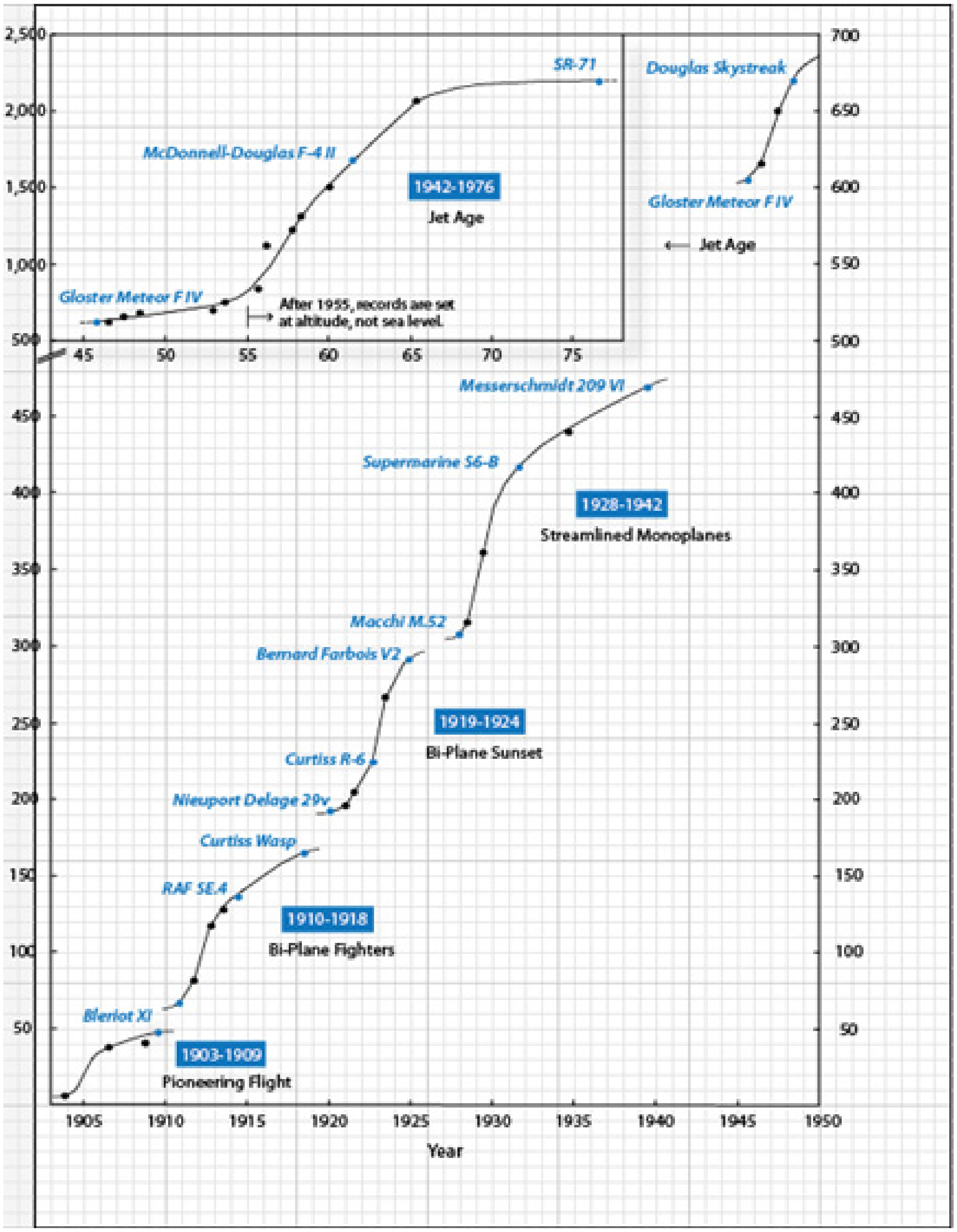
THE S-CURVE

Each of five successive curves traces a similar pattern: a sudden jump to higher speeds, followed by an accelerating, then a declining rate of improvement – only to repeat.

World Aircraft Speed Record: 1903-1976 (miles per hour)



DRIVERS BEHIND THE CURVE

Each curve reflects the emergence and refinement of a *dominant design*: a better way of configuring continually improving system resources to achieve higher performance. But as each curve reveals, speed improvements soon decline as the design pushes up against a *performance ceiling*; a physical limit that no amount of design refinement can overcome. Below, we examine each curve in turn.

Pioneering Flight (1903-1909): The performance goal was to avoid crashing. Designs were trial and error: monoplanes, biplanes and triplanes, even multiplanes resembling venetian blinds.

But biplanes prevailed: two wings generated high lift at the low speeds attainable with the era's heavy, underpowered engines.

Biplane Fighters (1910-1918): flew faster using more powerful rotary engines. But they soon hit their physical limit: high drag from the extensive external struts and wires needed for wing bracing.

Biplane Sunset (1919-1924): Streamlining and more powerful engines pushed the biplane past 200 mph. The last biplane to win the world speed record (1924) flew over 230 mph. But no amount of streamlining or raw horsepower could overcome the extra drag of two wings versus one.

Streamlined Monoplanes (1928-1942): Reached 440 mph by 1935, through improved wing design, retractable landing gear, supercharged engines, and better fuel. The best World War II fighters could fly even faster, reaching *transonic speeds*[2] in a dive. But this could result in severe buffeting and even loss of control. Aircraft were catching up with their own sound, waves of compressed air that acted like an invisible wall in the sky: 'the sound barrier'.

The Jet Age (1942-1976): The sound barrier was first broken in 1947. But it would take significant design innovations including the jet engine, swept wing, fully-moveable tailplane, and 'coke-bottle' waist: to overcome the huge increase in drag at transonic speeds and routinely achieve supersonic flight. The long, slow increase in fighter speeds during the postwar era underlines the many systems challenges that had to be overcome.

The Ultimate Physical Limit (1976): Proved to be heat from air friction, sufficient to soften airframes' aluminum alloys at high speed. The SR-71 Blackbird spy plane (right) reached 2,193.2 mph (the official record). Some of its surfaces reached 800°F, necessitating titanium alloy construction and the use of special fuel as a coolant – in spite of operating in the cold, thin air above 80,000 feet.

IN SUMMARY: THE SYSTEMS DIMENSION

The performance of all technology systems evolves along highly predictable lines: the s-curve. Successive design eras are reflected in the multiple s-curves. Doyletech has applied the systems model to help policy makers to understand the dynamics of technologies that range from electric cars and aerospace to semiconductors, housing construction, and printable electronics.

Design eras are critical; they are driven by a set of codified ideas that shape systems and how they operate. Just as ideology[3] influences how entire societies live and work, design has a powerful influence on technology systems in the tight circles of industry. Designs are a combination of philosophy, hard-won experience, norms and standards, rules and insights. Design eras shape the playing field of competition and ultimately what products can do.

[2] Transonic speeds range from roughly 0.8-1.2 times the speed of sound (768 mph in dry, 20°C air at sea level), i.e., the lower end of the transonic range is ~614 mph at sea level – and declines with altitude.

[3] See "Why Technology Takes Time to Break Out: Culture's Role in Commercialization".

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is a series of articles that explore how technology is reshaping the economy and serves to better inform decision making in business and government.

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