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# Industrial Design in Aerospace/Role of Aesthetics

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# Industrial Design in Aerospace/Role of Aesthetics

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## Introduction

Industrial design creates and develops concepts and specifications that seek to simultaneously and synergistically optimize function, production, value and appearance. The inclusion of appearance, or esthetics, as a major design metric represents both an augmentation to conventional engineering design and an intersection with artistic endeavor(s). Obviously appearance is in connection with, and with respect to, human presence and interactions-in-the-large. Appearance, per se, is a component of human factors and includes considerations of human characteristics, needs and interests. Appearance in this context refers to all visual aspects – the statics and dynamics of form(s), color(s), patterns, and textures [including reflectivity] – the “look and feel”, the “experience”. Appearance/esthetics affects humans both psychologically and physiologically and proffers opportunities for improving both human efficiency and “attitude” – thereby increasing overall productivity and enjoyment. Zeroth order general aesthetic/appearance guidelines include “soft curvatures” and “warm colors”, perhaps indicative of a specific evolution-induced predilection for “naturalistic” forms and hues.

Industrial design per se dates from the 1930’s and apparently, at least in the U.S., resulted from the application of Art Deco styling to mass-produced consumer products for enhanced salability in the markets of the depression and later decades. Early on, industrial design incorporated “streamlined” forms borrowed/derived from aerodynamics and bionics, with particular emphasis upon “teardrop” shaping with multitudinous applications to moving, stationary with flow past and truly/globally stationary objects/devices. There has thus long existed a close relationship, both in terms of style and frontier technologies, between aerospace and industrial design. Classic early examples include the Chrysler “Airflow” and the Buckminster Fuller “Dymaxion” Automobiles. This often pervasive influence of “aerodynamics”/aerospace upon industrial design continued

through the 50's with "finned" automobiles and up to the present, as is often discussed in various media articles and reviews. The purpose of the present work is to explore the far less often examined inverse influence – the effects of industrial design upon aerospace, with emphasis upon the appearance/aesthetics aspects.

### Relatively Unique Aspects of the Aerospace Design Context

Atmospheric Flight – Appearance/aesthetics in aerospace design must at least co-exist, if not be synergistic, with the overall/societal fundamentals/metrics of aerospace engineering design. These metrics, for atmospheric flight, were dominated for years [up to the 70's] by the higher/faster/farther mantra and resulted in aircraft cruise altitude increases into the 35K to 60K foot + regime, speed increases up to Mach 3 plus [the SR-71], and ranges beyond 6,000 miles. Since the 70's, the overall/societal aeronautical metrics have shifted toward [airspace] productivity, safety, environmental issues such as noise/emissions and "affordability"/competition. Solutions to these aeronautical metrics are sought, for a given design mission, within the dominant technological parameter space of weight and drag minimization and propulsion efficiency [the components of the "range equation"] and the "illities" – including producability, maintainability, reliability, flyability, inspectability, flexibility [response to market changes] repairability, operability, durability, and airport compatibility. There are also extensive design "marching orders" and issues to be addressed emanating from the economic and regulatory aspects of the aeronautical "business".

Few technological arenas are as sensitive to/critical with respect to weight than aeronautics. This weight sensitivity necessitates utilization of the latest "matured"/"safe", affordable etc. developments in light weight/high strength-to-weight materials, special structural designs/approaches and perhaps the lowest credible design "factors-of-safety" extant in industry. The latter is enabled by very extensive analysis and testing to ensure accuracy of both design loading and structural/material stress levels. This in turn results quite often in "elegant"/svelte-to-minimalist appearing/"pleasing" designs.

On the equally important drag issue great care was taken early on to reduce the drag component still most prevalent on most other transport – form or pressure drag resulting from separated flow(s). Aircraft cruise drag [except for rotary wing devices] is, not surprisingly, quite low and almost equally distributed for conventional transports between attached flow skin friction and [vortex] drag-due-to-lift, the latter resulting from the [finite

span] upwash at the wing tip/formation of wing trailing vortices. To further reduce drag external surfaces are relatively smooth to reduce “roughness drag” and various wing tip designs and devices [many “borrowed” from nature/bionics] are used to reduce the strength of the wing tip vortex.

Spacecraft/space access – The technological metrics for the “space” side(s) of aerospace are largely similar to aeronautics with a few major differences. For current space access approaches [rockets] the supremacy of drag is replaced by thrust and lift is relatively unimportant – thrust and dry weight are “everything” in terms of major design metrics. Increasingly the overall metric for space access has become “affordability”, in terms of “dollars-per-pound” [of payload] to orbit. Most of the “illities” still apply. Once in space drag per se is obviously no longer an issue. Propulsion/thrust is still a major issue for “orbit raising” [from LEO to MEO/HEO/GEO] or climbing out of the Earths’ gravity well for travel within or beyond the solar system. Obviously “streamlining” is no longer required if there are no streamlines/no appreciable fluid flow past the body, such as in “space”. Spacecraft are typically “shrouded” during launch, mainly for protection from heat and “wind” [flow] damage. Once in space the shroud is jettisoned and the spacecraft “exposed” to carry out its’ function(s).

Human “Presence” – The “Introduction” section indicated that the appearance or esthetic component of industrial design is wholly within the context of human presence and interactions – in terms of both purchase/sales and operability/usability. What is different concerning “space” per se [beyond LEO] is the nearly complete lack of human presence. Space exploration and “space-based earth utilities” such as communications, navigation, remote sensing [e.g. weather] etc. [aside from the Apollo program of the late 60’s-early 70’s] has been and is conducted via robotics. This is at least partially due to the almost 50-to-1 plus cost differential between the two [“manned” and robotic]. Also, almost all the satellites operate at their various orbital positions outside of human presence/sight. The sparse human “presence” in LEO involves the space station(s) and the relatively few “human-rated” space access systems such as the U.S. Space Shuttle and several international rocket systems.

Therefore esthetics in aerospace is largely connected with those portions of the overall aerospace endeavor which involve human interactions – essentially all of aeronautics [both “external” and “internal” aspects] and the internal portions of manned space flight, in terms of both space access and

space presence/in-space transport. The “internal” aspects of aerospace can be further delineated into Flight decks and “cabins”. Overall, these define the industrial design – appearance/esthetics/human-centered “playing fields” of aerospace.

### Example Impacts of Industrial Design [Appearance/Esthetics] Upon Aerospace

Rotary Wing – The EC 120 Eurocopter project was begun in 1992 and is, according to reference 1, the first Eurocopter helicopter to incorporate industrial design from the beginning of the design process. This decision was evidently prompted by the previously highly successful experience of Bell Helicopter, whose Jet Ranger was the result of considerable industrial design input, including new fuselage styling. The Jet Ranger became the worlds’ best selling turbine helicopter. The major applications of industrial design precepts in the case of the EC 120 involved the interior portions of the aircraft.” The aircraft had to be esthetically pleasing for the next 30 years...ageless for decades”. In the overall design they accomplished this via a “natural balance of volumes, harmonious interaction of shapes and extreme simplicity of lines”. The interior was especially designed to conform to body shape and outfitted for ease of installation/replacement of pleasing but functional modules such as tables, a mini-bar, and a telephone/intercom. The layouts and fittings were designed after extensive discussions with pilots, mechanics, operators, and passengers.

Space Stations and space “habitats” – Esthetics are especially important to the crew of space stations due to long duration confinement in [very] limited interior space in micro-g with little-to-no real variability in environment other than the “ultimate high” – looking out windows at the “Earth going by”. It is of interest that windows were installed in the first U.S. space station – Skylab, at the suggestion and insistence of one of the all time pioneering “Greats” in Industrial Design – Raymond Loewy. They proved of inestimable value to the success of the entire program. Deprivation experiments indicate visual disturbances, illusions, and restlessness can be caused/due to/characteristic of reduced environmental variation.

A fascinating study in 1989 [reference 2] indicates that test [crew] subjects, when asked to evaluate a large bevy of photographs and paintings as potential “interior decoration” within the space station preferred those with the greatest apparent depth of field, irrespective of topic. This was taken as



an indication that “the opportunity to look outside of a confined environment is a very desirable attribute that can be simulated by spacious photographs and paintings of landscapes” [and possibly, in future years, by holograms and virtual reality – it really is “all in our heads”]. Hospital studies indicate a view of trees and bushes leads to a speedier recovery. Moist/water containing scenes appear to be more soothing than arid ones, natural scenes better than those of man-made objects/environments and spacious scenery better than densely populated [psychological/physiological “health” /improved attitude metrics].

Other space station interior esthetics studies indicated the efficacy of soft pastel colors with added contrasts to provide “up/down” cues in the micro-g environment including a white/sky simulation “ceiling”. Also and throughout, care should be taken to minimize glare/highlights. Lighting, texture and color should be simultaneously designed for effectiveness of both work and rest periods/places. Of particular interest is the concept of dynamically and spatially adjusting lighting color(s) and intensities to conform to daily and even seasonal biorhythms including simulated snowfalls, rain/wind storms etc. This tends to mitigate the “societal separation” effects by providing some semblance of ‘inclusion” in terrestrial processes. Accompanying suitable auditory backgrounds/cues are also efficacious.

Given current interplanetary propulsion technology human exploration expeditions would involve years, rather than months, with much of that time spent aboard very cramped space transit vehicles and the rest in “habs” on the planet. From reference 3 “Mars transit vehicles and surface habitats will constitute highly confined, technical settings characterized by social, emotional and physical deprivation while affording little opportunity to experience privacy or environmental variation”. Therefore, all of the esthetic/appearance precepts discussed in connection with space station interiors become even more important for human space “exploration” of the solar system [and, eventually, beyond...] with emphasis upon “naturalistic” “countermeasures” to the innate/multitudinous stresses of such expeditions.

Airline Passenger Cabins – The prime esthetic elements within the passenger cabin of commercial airliners include seat fabrics, carpets, plastic fascia, antimacassars, bulkhead decoration(s), painted surfaces and lighting. Specifications of these elements offer the airlines opportunities to both assert their corporate identity [to build customer identification and loyalty] and improve the passenger “flying experience” – critical to success in a very competitive business. Since space is “physically defined but psychologically

perceived...strategic use of light, mirrors and color can combat the potential claustrophobic effects of these confined areas and create the illusion of greater room than actually exists” [reference 4] – well known to interior decorators worldwide but especially important for/in the highly confined/minimal interior space typical of transportation devices. Particularly interesting in regard to color is various cultural norms and proclivities – for example white represents mourning in Asia vs. black in most western countries. At least one airline manufacturer has committed to create “Innovative products that exceed functional expectations and also convey an element of delight .The quality of fun has to be transparent”. This particular company has an industrial designer sitting on its’ management committee.

Obviously, the “interior design” of passenger cabins carries with it usual cost, weight, and various safety constraints as well as an overall cylindrical geometry with a repetitive pattern of windows. Newer fuselage designs such as the new giant jetliner manufactured by Airbus or the blended wing body would immensely increase the interior design option set, essentially change [much of] “everything”, as would an [unlikely] return to the extensive cabin areas allowed by dirigibles. The engineering parameter space within which interior [esthetic] design must function includes flammability, smoke/emissions, certification/testing, regulatory strictures and wear resistance.

Airliner Flight Decks – With some 70%+ of aviation accidents attributed to some type of “human error” the industrial design of flight decks is obviously a critical issue. The crew must maintain the requisite mental acuity/alertness required to carry out what are literally life and death responsibilities. Such mental alertness is increasingly difficult in the face of ever-increasing levels of automation where crew are monitoring much more as opposed to “doing”, although there are conscious overall efforts to ensure meaningful human interactions with the automated systems. “Monitoring” tends to instill boredom and complacency which are obviously undesirable states. Therefore, as opposed to the passenger cabin where “comfort” is an important metric, in the cockpit the major task for interior [artistic] design is alertness. This “attention getting”/alertness mantra extends throughout the flight deck and includes displays, alarm systems and controls as well as “interior fittings”. A real danger is providing the crew with “too much information” with attendant sensory/perceptual overload. From reference 5 key flight deck display “appearance” issues include visual accessibility, location/arrangement of components, legibility/adequacy of information and

use of color and size/shape of display elements. This is all in the present day context of “glass cockpits”/electronic displays/”touch screens” as opposed to the vast arrays of round and other configuration(s) gauges, meters, buttons/levers etc. characteristic of the aircraft “control panel” of previous generations. Care has always been taken, via physical “glare shields” etc. to obviate glare on the instrument panel – to avoid interference with crew effectiveness/functionality.

Taking as a recent example the flight deck of the Boeing 777, “close attention was paid to aesthetic detail”, [reference 6] including use of smooth and soft contours/curvatures, few seams, functionally contoured cup holders and use of warm colors for enhanced alertness.

External Styling/Esthetics of Aircraft – As is well known, external styling/appearance/esthetics has an over-riding influence upon the sales/business of automobiles. A, perhaps classic, example in this regard being the Edsel – a quite advanced automobile technically but far from successful due to styling difficulties. People willingly pay premium prices for attractive autos with “performance” not very different from, or even inferior to, models costing far less but having far less attractive styling. All this is obviously a bedrock testimony to the [market] importance of industrial design. It is interesting to note that this situation holds for individual automobiles to a far greater extent than for fleet sales or commercial vehicles.

A similar difference in the importance of styling is apparent in the aircraft market. Large commercial aircraft, following their initial styling developments of the 30’s and 50’s [“rounded noses, organic curves” – typified by the DC-3 and 707] are primarily “styled” more recently and today via airline color schemes and logos as opposed to actual [perhaps prohibitively expensive] changes to the external configuration. Such configuration changes in transport aircraft have, especially over the last 3 decades, been glacial at best. However, the situation is very different in the personal and even corporate jet world. Here styling in the sense of external configuration appears to be far more important from a marketing/enjoyment standpoint, although no-where near the over-riding issue that it is in the automotive world. This is at least partially because there are few external features on an aircraft that can be modified without significantly altering performance – although wholly new design/performance paradigms either exist or are feasible.

An interesting case-in-point regarding the influence of external styling on small “general aviation” aircraft is the Beechcraft Bonanza from Beech

Aircraft Corporation. There were extant two versions of this aircraft with different tail configurations: a 3-component/conventional “straight tail”; and a 2-component “V-tail”. The latter was unique/distinctive and much sought after/desired. The V-tail model also sported a plush interior. In spite of a factor of 8 greater incidence of in-flight breakup for the V-tail compared to the straight tail Beech Aircraft sold some 10,000+ V-tail aircraft – a major production run for aircraft. For many years it was “The Hottest Plane On The Market”.

Current private aircraft manufacturers almost universally and specifically target style/appearance/industrial design as a competitive advantage and highlight such in their marketing. This pertains equally well to both the external and internal aspects of the aircraft. Typical external features touted as “different” /stylish include canards, “strutless”, V-tail, “retro”/classical, gull-wing doors and distinguishing paint schemes/ "artwork”.

### Aerospace Industrial Design Tools

The trend in design tool development, for over three decades, has been to ever increasing computerization. This overall trend has more recently been joined by a rush [enabled by further developments in information Technology”] toward multiple site simultaneous and asynchronous collaborative design and increasing utilization of “projective”/immersive visualization approaches beyond “flat screens”/3-D graphics – both holography and “Virtual Reality”. The optical communications are supplying the band width for “VR”, the requisite computer capability is available, haptic taste, touch and smell have purportedly been patented and work is progressing beyond “fooling the senses” to direct inputs into the senses/neurons and perhaps eventually directly into the brain. The overall assertion is that beyond the industrial age, and beyond the IT/Bio/Nano age, which is succeeding the industrial age, is the Virtual Age... This visualization technology has largely superceded conventional “model-making” - being much faster, far more affordable and extremely adaptable to real-time alterations/"development” as well as fit/form/function and perspective/appearance.

Major CAD/CAM/CAE software, such as CATIA [Computer Aided 3-D Interactive Application], utilized by Boeing Aircraft and others [ref 6] is both a concept development/design tool and a communication tool – allowing both industrial designers and development engineers to work both interactively and simultaneously. Such automated/animated design tools are

reducing the design cycle by factors of order two thus far while greatly improving almost every aspect of the product and minimizing expensive production “rework”. CATIA is only cited as an example of a huge number of such industrial/engineering design tools produced throughout the world. CATIA, for example, is a French product from Dassault Systemes. A current NASA-evolved collaborative infrastructure tool is appropriately named DARWIN, presumably inspired by the evolutionary design process enabled by such capability. Communication capability exemplified by the Internet and these automated/interactive multi-discipline design/visualization tools enable the current [economically driven] aerospace mantra of “Design Anywhere, Build Everywhere”.

In the future the automated design function will advance to higher conceptual levels as learning machine intelligence develops concurrently with/is enabled by the tremendous computer capability increases anticipated via “beyond silicon” [bio, optical, quantum, molecular, nano/nanotube] computing.

### Concluding Remarks

Histories of industrial design tend to highlight the aviation/aerospace and automotive arenas as prototypical examples of the impacts and importance of industrial design. Aviation early on contributed “streamlining” to the industrial design lexicon and toolkit/practice. However, streamlining in aviation, as indeed designs/precepts in much-to-most of aerospace practice, occurred as a functional/engineered response to technological realities, not as a particularly conscious effort to create a pleasing style/aesthetic. The popularity and impacts of streamlining, including the subjective impacts, are perhaps and interestingly a result of a relationship to numerous natural forms. Many of the “forms” encountered/utilized in aerospace applications do in fact possess “beauty” but this beauty derives, in most cases, not from a conscious attempt on the part of the designer to create such but rather, in a manner similar to the genesis of “natural” beauty, results from what is essentially a constrained/evolutionary “survival of the fittest” Darwinian process. As a speculation there may be a deep seated human proclivity toward the results of such “natural” processes, especially if the results appear at some level to be similar to/related to “natural results”. The various utilitarian/minimalist design schools/movements have, at least thus far, always cycled back to “natural” themes and forms.

Overt attempts to produce esthetically pleasing products [via industrial design processes/precepts] are prevalent in aerospace for the arenas discussed herein – [aircraft and spacecraft] cabins and flight decks and the exteriors of small aircraft. The extent to which an externally esthetically pleasing product is produced in the areas of large aircraft and space access devices per se is probably a “natural” occurrence. It is interesting in this regard that a chronology of the highlights of 100 Years of Design [Ref. 7] includes the external appearance/styling of 2 aircraft – the Douglas DC-3 of 1935 and the Boeing 747 Jumbo Jet of 1969.

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