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The Anthropology of Aviation and Flight Safety

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This article examines the anthropological issues posed by commercial aviation, an industry that in less than a lifetime has changed the meanings of space and place, and altered fundamental perceptions of global civilization. The article begins with a critical examination of the concept of "human factors" as the standard industry approach to the human role. It notes that the representation of flight, as a mass transportation mode, has not kept pace with the global deployment of this technology across multiple cultural regions. The article notes that commercial aviation, as a large-scale technological system, has been deployed on a global scale yet is only weakly governed by United Nations bodies and multilateral arrangements among air carriers. The article concludes with the observation of a process of technological peripheralization, arguing that technologies that promise an escape from economic marginalization can often promote technological marginalization.

Key words: aviation, large-scale technological systems, safety

Commercial air travel, along with automobiles, computers, and electronic communications, has reshaped the contours of contemporary civilizations, touching the lives of villagers and elites alike. Assumptions about time and distance, about space and place, about community and communication, have all been upended by these four technologies.

In this article I wish to examine the anthropological issues raised by the industrialization of one of these technologies, commercial air travel. The commodification of long-distance travel, along with telecommunications, has altered the personal and societal radii that once defined human scale and hence the frontiers of anthropological understanding. The border phenomena of anthropology today are found not in New Guinea, but in the large-scale social representations implicated in large-scale technological systems: these systems include power generation and distribution, biotechnology, and civil aviation. Among these concepts and images are "human factors," a humanity decomposed and redesigned for improved adaptation to the technological system. Like other colonial projects, "human factors" redefines space and place, creating new opportunities for adaptation and new forms of peripheralization.

I will first characterize human flight using conventional anthropological views (The Culture of Flight) and present an alternative view from a group of French anthropologists (Face a l'Automate). Circling closer, I will then place the industry's view of humanity (Design and Decomposition) within the context of the *fin de siècle* problematic of commercial aviation (The Regulation of Large-Scale Technological Systems). I propose a new anthropology for these new phenomena (Toward an Anthropology of Large-Scale Representations), and close with a consideration of the alternative: a world in which technological progress creates new forms of dependence and insecurity (Postimperial Peripheries).

The Culture of Flight

Commercial aviation is one of the youngest industries, roughly the same age as consumer electronics and broadcast communications. Commercial aviation in the United States evolved out of the 1920s airmail service of the Army Air Corps. Until it was rationalized at the behest of the postmaster general, commercial aviation was a hodgepodge of small, inefficient carriers, and unconnected routes.

A large-scale technological system, such as transport organized on a continental scale, presents a delicate balancing act among central sources of supply, regional demands, and

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network integration. Electric power transmission, mechanized transportation, and industrialized agriculture are all large-scale networked technical systems. Their balance of supply, demand, and network performance is maintained only through government or monopolistic sponsorship and regulation. From an organizational point of view these systems represent an adjustment between distributed (network) and hierarchic (bureaucratic) control. In aviation, the technological issues of balancing a large-scale network are complemented by the business requirements of combining profitable operation with safety and passenger comfort and convenience.[1]

In 1959, when Boeing introduced the first jet airliner—the 707—this balance was altered. Widebodies, such as the 747, introduced in 1970, upended the economics of the industry. Widebodies created an overcapacity that drained money from the industry even as de-regulation in the late 1970s opened the door to yet more capacity. Deregulation permitted the airlines to compete on the basis of ticket prices, once more extending the affordability of flying. As a result, within a generation flying has gone from an elite experience to something as commonplace and democratic as boarding a bus.

For most of its history, going back to Warner and Low's (1947) study of the social system of a modern factory, industrial anthropology, like industrial psychology, has concerned itself more with descriptions of industrial workplaces than with industrial systems or industrial civilizations. Classic studies of tin miners (Nash 1979), textile workers (Ong 1987), locomotive engineers (Gamst 1980), and health care workers (Sacks 1988) provide a clearer view of the industrial workplace, particularly on the capitalist periphery. Production, however, is only one element of the industrial picture: industrial civilization also requires that distribution, consumption, and administration be regimented on an industrial scale. The literature of industrial anthropology currently embraces an array of studies of industrialized consumption (Miller 1998, or Appadurai 1986, for example) and administration (Fiske 1994, or Gregory 1983, for example). These, along with the studies of industrial production do not yet add up to an anthropological approach to industry that is as comprehensive as anthropological approaches to nonindustrial societies (but see Santos Corral 2000 for an exception).

Large-scale technological systems generate their own array of cultural innovations, even as they massively rearrange existing cultural forms. The cultures of aviation, among managers or pilots alike, are male-oriented, with bravado, strutting, and fascination with machinery supplying the dominant themes. Around the world pilots constitute a unique group, characterized by an ensemble of physical abilities (eyesight, motor skills), background (flight training), initiation rite (the solo flight), and stylized dress.

The *culture* of aviation, the remaking of human culture through flight, consists of a set of representations and mediations that defy the gravitas of conventional cultural forms. Concepts of distance and familiarity, like markers of status, have all been altered by this new large-scale system.

In the history of aviation one can observe overlapping yet distinctive images of the experience of flight and its place in human affairs. Before the mid 1930s, civilian flight was a matter of carnival demonstrations and courageous airmail pilots, braving storms and the unforgiving skies to get the mail through. From the 1930s to the 1970s commercial flight was only for elites. High fares restricted access and business attire was de rigueur. In the 1970s airlines such as Southwest and PSA learned how to evade fare-and-route regulation, and in 1979 the U.S. Federal Aviation Administration (a pattern-setter for the rest of the world) de-regulated the entire domestic industry, offering the experience of flight to the hoi polloi. World deregulation soon followed. Flight opened the iron cage of locality, so that Amazonian villagers and Canadian Inuit alike could have their bodies and their sensibilities transported to Sao Paulo, Toronto, or London. Today, in any medium-sized city, the experience of rubbing elbows with representatives of other cultures is democratic and ordinary, and the separations of cultures have been replaced by a separation of culture and technology.

Human flight is an experience of perfection: in flight, polished skills and highly engineered devices enable aviators and their acolytes to transcend normal human limitations. The devices are significant: it is the marriage of man (yes, man) and machine, or more accurately the subservience of man to machine, that enables this transcendence. Those who submit are allowed to enter the sacred spaces of flight: the control tower, the flight deck, the sky. In these sacred spaces "human factors" are almost an afterthought, a grudging acknowledgment or faintly heretical statement that there might be a concern for adaptation between this excellent machinery and the imperfect humans who depend on it.

In the last 20 years, aircraft have become more highly automated, with flight management computers, autoflight controls, datalink with air traffic control (ATC) centers, and "glass cockpit" cathode ray tube (CRT) displays displacing the gauges and dials of a conventional flight deck. Faced with these developments, the lagging engineered device, the "human factor," which aviation invented 60 years ago, must struggle to adapt. Indeed, one might suggest that the recent profusion of human factors literature (Wiener and Nagel 1988; Johnston, McDonald, and Fuller 1994; Garland et al. 1999), which explores the relationship between flyers and flying, is a direct consequence of the rapid growth of flight technology.

Face a l'Automate

Human factors tends to be an Anglophone phenomenon, with psychologists and engineers in other world regions proposing alternative paradigms. One alternative to the human factors approach to flight automation is presented by a group of French anthropologists and information scientists. In a wide-ranging book, *Face a l'Automate: Le pilote, le contrôleur, et l'ingénieur*, Alain Gras, Caroline Moricot, Sophie Poirot-Delpach, and Victor Scardigli, examine commercial aviation as a "large-scale technical system," drawing on the work of Hughes (1983). In this large-scale system, which found a social and representational niche for what was once considered a "useless object" (Gras et al. 1994:12) three critical roles—pilots, controllers, and designers—are today faced with a common problematic, the transition from analog to digital displays of the flight situation. Believing in the perfectibility of society through engineered devices, designers of contemporary aircraft install numerous devices intended to gain the greatest aerodynamic and propulsion efficiency. Today there is extensive use of digital technology and displays on the flight deck and in the control centers. As a consequence, the roles of the pilots and the controllers are being changed in profound ways.

Drawing on the concepts of Levi-Strauss to analyze the structure of myths to reveal unknown or forgotten social facts, Gras et al. (1994) note that the two accepted representations of human flight are those of the ideal of free flight, as represented by Icarus, and the image of total control as represented by *l'oiseau mecanique* (mechanical bird). Icarus places the pilot in charge and has profound consequences for the design of procedures, organizations, and technologies; understandably this is more in conformance with the pilots' image of themselves. The "mechanical bird" envisions the aircraft as but one moving part in a vast technological assemblage, subject to positive control from air traffic control (ATC), Datalink, and flight automation. L'oiseau mecanique is the guiding *imaginaire* for equipment designers. Seated in the cockpit of l'oiseau mecanique the pilot is but one more link in a production chain, and the least reliable link at that.

To this I would add two other representations, the "winged chariot," and by extension the "flying omnibus." Both emphasize transportation rather than flight, may well be more appropriate to commercial air transport, and are embodied in the latest generation of commercial transport which, after all, comes from a company called Airbus Industrie.

On modern flight decks, digital displays and controls have altered the pilots' perception of airspace and their navigational tasks in ways that are still not understood. Numerous recorded instances of "mode confusion" (Learmount 1998), where the pilots did not understand the autoflight mode behavior of the aircraft, are ample testament to this.

Gras et al. (1994:73) note, in describing the role of aircraft designers, that these engineers, like others, are remaking the world and humanity in a manner

> in line with the philosophy of Descartes (the whole universe can be broken down into elements governed by the same laws), of Pascal (to distrust the physical body and its passions; to deny the existence of chance through the theory of probability)…and last, of 19th century positivists (the engineers being entrusted with a social mission—progress in science and industry is progress for humanity).

Whether or not this "digital human" is mankind's preferred future is seldom considered in the design of these systems. To this, the authors add, in describing their research approach,

> We distance ourselves from the concepts of human factor and human error…as categories of causality. Human "functions," human "factors," is it not by chance that this vocabulary is borrowed from biology in the 19th century and from mechanics in the 18th century—the age when the first French engineering academies were founded to lead humanity toward Progress. Even in the time of Pascal and Descartes human beings could not avoid the universal method of "understanding" the world, i.e., everything, from the atom to planets' trajectory, could be broken down into simple elements. (ibid.:7f.)

A challenge for an anthropology of aviation, which Gras et al. present, is to travel a similar distance from "human factors" to an understanding of the emergent phenomena and subtle connections within human contexts and their integration on a global scale. Let us begin.

Design and Decomposition

Aviation human factors began as a discipline in the early years of World War II, when it was realized that more crew were dying from their own errors in piloting than from enemy fire. Wartime stress and fatigue, together with technological advances in speed, maneuverability, and (aircraft) endurance, required a rethinking of the selection, preparation, and operational routines of the flight crews. The total mobilization of a world war placed tens of thousands of aircrew in the most technologically advanced devices then known to humanity, with the fate of Western civilization hanging in the balance.

It is this tension between democratization and technological advance that created the need for human factors as a specific approach to integrating man and machine. Improvements in aviation technology created new challenges for the relationships among the crew, the environment, the self, and other crew. As aviation became organized, the relationships between the aircrew and the organized regulation of flight became the next human factors challenge. As long as flying was reserved for a small handful of courageous lone eagles, these challenges could be met by self-selection and Darwinian attrition: only risk takers with good eyesight and motor skills would go into flying; those who didn't measure up fell out of the sky.

An initial human factors challenge for aviators was to know which way the plane was going, and it was addressed with a piece of string. When flying an airplane, it is essential that the aircraft be in trim along three axes: pitch (nose up or down), roll, and yawl (the direction the aircraft is moving through the air in relation to the direction in which it is pointed). Too much yawl and the aircraft will slip during a turn and skid out of control. Very early, pilots began attaching a piece of string to a frame member, and by keeping the fluttering string parallel to the fuselage, they could be assured that they were going in the direction they were pointed.

This little story illustrates a key point: in flight, unaided human senses are inadequate for controlling the aircraft. Maintaining trim, airspeed, and navigational axes in most situations exceeds human capabilities and requires instrumented support. Some of the earliest human factors research studied instrumentation requirements and design, determining just how much information about the aircraft and its environment was needed by the pilot. Today even the simplest aircraft has flight instruments to monitor airspeed, trim, and altitude.

Other initial concerns of human factors were with crew physiology. With aircraft continually setting records for altitude (above 20,000 feet by Georges Legagneux in 1913), speed, endurance, and maneuverability, they stressed the human body's ability to function. A tight turn, like high altitude in an unpressurized cabin, can cause a loss of consciousness. Studies of fatigue, endurance, circulation, and eyesight, along with the biomechanics of flight decks, have enabled humans to fly aircraft faster, higher, and farther.

Some of the more recent challenges addressed by human factors include relationships among the aircrew, summarized under the heading of "crew resources management," and relationships with management, summarized under the heading "safety culture." On the flight deck the introduction of technology (autoflight, flight management computers, navigational aids, communications), while improving the economy and extending the performance of the aircraft, has stressed the capabilities of the crew. Unlike the Ryan NYP, which Charles Lindbergh flew solo from New York to Paris in 33 hours, a modern-instrumented aircraft requires the coordinated effort of two flight crew, in which one (either the captain or the first officer) controls the aircraft, while the other monitors traffic, environment, and communications. In a commercial airline the captain and first officer rarely have a close relationship; a typical duty tour begins early in the morning with the captain introducing himself to his first officer in the dispatch center and then briefing the crew. To achieve smooth coordination between captain and first officer, numerous airlines have created programs of crew resources management, or CRM.

CRM is a training discipline that teaches pilots to communicate effectively, to work as teams, to monitor situational awareness and fatigue, distribute workload, and to exercise consultative decision-making skills, all with crew members with whom they are probably personally unfamiliar: in short, to work as an experienced team from their very first takeoff together. CRM has acquired a quasi-religious cachet among leading airlines, as pilots attribute improved safety and the avoidance of disasters to the skills they learned in CRM classes: When Captain Al Haynes, of United Airlines, brought a crippled DC-10 to a nearly successful landing in Iowa City, Iowa, in 1989 after it had lost all flight controls, he attributed the success (in which he saved 185 lives) to coordinated effort with two other crew in an exceedingly stressful and demanding situation.

CRM substitutes an engineered skill set for the local adaptations of teamwork that are learned by sports teams and musicians over the course of prolonged, mutual familiarization. This decomposition of human attributes into "resources" is notable, as is the implicit assumption of a rationalized style of authority called "management." Although these concepts have without question prevented numerous accidents, particularly in Europe and North America, their acceptance in Asia, Africa, and Latin America has been more problematic (Helmreich and Merritt 1998 supply some examples).

Part of this lack of acceptance, one might hypothesize, is that CRM is based on a strategy of analytic decomposition and on a set of individualistic assumptions concerning authority. Western concepts of management presume that authority is vested in the office, rather than the person (Weber 1956:125), and that the strict limits on authority include an affordance for mutuality ("speaking up") that mitigates any overreach by the person in the commanding role. Jing Hung-Sying et al. (2000), by contrast, observe that in Chinese and other Asian cultures authority is considered absolute, that it is a matter of personal obedience, and that a first officer would never dare to speak up to his captain. These differing perceptions of authority suggest that CRM has a dissonant message among nonwestern crew.

It is likewise with "safety culture," a constituent element resulting from a decomposition of culture. In recent years safety culture has been recognized as essential to safe operations in both aviation and the nuclear power industries (Rabinowitz 1998; Ostrom, Wilhelmsen, and Kaplan 1993; Pidgeon and O'Leary 1994). Considered as a set of homilies toward prudence, following rules, and communicating openly, one can hardly fault the concept of "safety culture," although its provenance and sustenance remain open questions. By decomposing the habits of the heart into elements sized to a designer's checklist, one eliminates from view the ineffable impulses that distinguish cultures from commands. In a list focusing on specific items such as reporting systems (check), open communication (check), nonpunitive fact finding (check), and adherence to standard operating procedures (double-check), there is no formatted space for a dialogue that might construct a shared perception of operational risks.

When two complex systems are required to adapt to each other, either one can be decomposed and "retrofitted" to the other, or the two can "coevolve" as both learn from the miscues of misintegration. Coevolution can be a gradual process of mutual learning, or a shotgun marriage in which the two systems face a common environmental threat of adapt or die. The wartime urgency that gave birth to human factors did not allow time for mutual learning, and the wartime technological imperatives of the last 60 years (inasmuch as neither the military nor the economy demobilized at the conclusion of World War II) have dictated that humanity should be retrofitted to aircraft systems, rather than the other way around.

Although this is a modest oversimplification of both the problem and a complex literature[2] it is unarguable that human factors, *as a branch of engineering*, uses engineering strategies and engineering discipline to solve an engineering problem: the improved performance of a large-scale technological system. When the social sciences support this strategy they strike a pose of positivism, with any insights of interpretation, of social construction, of discourse, and of historical conflict carried along as contraband.[3]

The Regulation of Large-Scale Technological Systems

As the miniaturists of the social sciences, anthropologists have specialized in small-scale societies and local segments of larger-scale systems. When anthropologists have pronounced on larger-scale phenomena, such as colonialism or dependency, it has usually been with the borrowed voices of historians, political scientists, or sociologists. Conversely, these disciplines have looked to anthropology and ethnographic methods for the fine lines and chromatic values that bring continental structures down to a humanly recognizable scale. For more than 50 years this has been a stable arrangement.

Large-scale technical systems challenge this. Unlike a loose-jointed colonial or national regime, a large-scale technological system introduces and organizes tight coupling and cultural complexity spanning a plurality of local and regional communities of understanding. Technological investment creates the requirement and the opportunity for tight coupling, while increasing scale means that the system will embrace yet wider varieties of local knowledge.

In organized systems, the attributes of *coupling* and *complexity* pose challenges for effective operation. As described by Charles Perrow (1984) (and others in a substantial literature and debate that I will only summarize here), system complexity can produce unexpected behaviors, as when, for example, a contractor loads an aircraft with "expired" oxygen bottles, not understanding the hazardous nature of the cargo being loaded (NTSB 1997). When tight coupling (for example, the proximity of the cargo bay to the passenger compartment) is added to complexity, small deviations can ramify throughout the system. Perrow describes these ramifying and amplifying deviations in complex and tightly coupled systems as "normal accidents," that is, accidents that were engineered into the system by virtue of its design. An alternative view, coming from a group of "high reliability theorists," states that such systems can be made safe by balancing strict operational accountability with autonomy pushed to the lowest levels, redundant monitoring, and constant training. Both the "normal accidents" and the "high reliability" views have in common is a dynamic view of systems rarely found in the literature of human factors, and almost never in the practice of regulatory authorities. Neither has yet added a comprehension of cultural complexity to their analysis of organizational complexity (Perrow 1984; LaPorte et al. 1991; Roberts 1989).

Systems analyses of the flight situation range from static characterizations of system elements in a single operational cycle to dynamic views of industry-scale phenomena. In 1990 Avianca 052 crashed on final approach to John F. Kennedy International Airport in New York. The proximate cause of the crash was fuel exhaustion and the crew's failure to declare a fuel emergency. This state of affairs came at the end of a long chain of errors, including an outdated weather report provided on dispatch, obsolete flight manuals, lack of CRM training, and miscommunication between the flight crew and ATC. This accident is presented in the aviation psychology literature as a classic example of a systems accident, although the level of system characterization is that of an array of interacting elements, with no description of system dynamics (Helmreich 1994). Weick's analysis of the runway collision of two 747s in Tenerife, Canary Islands, by contrast, does describe a deteriorating situation that led to a breakdown in crew coordination and situational awareness. On an industry scale, Rasmussen (1997) describes the tradeoffs among safety, economical operation, and operator workload as being managed by pilots' experimentation within the margins of safe performance. Amalberti (1999) describes the tasks of flying in terms of "dynamic cognition," in which a process of "cognitive betting" continuously trades off task completion with error management. Although Helmreich's analysis of the Avianca accident is frequently cited in the aviation literature, an appreciation of systems dynamics is only beginning to gain acceptance within the American aviation community.

Large-scale technological systems are far too complex and delicately balanced to be integrated either through local adaptations or market mechanisms. Technological integration involves the transfer of energy and information within a system that may be continental in scale, or even larger. In a market system the control loop is no larger than a single contract. In a technological system the control loop will (typically) span the entire system, in all phases of a multiyear lifecycle. Design decisions made by Douglas Aircraft 70 years ago in Long Beach, California, affect African villages even today, with every landing and departure of a DC-3. Design decisions constrain operational possibilities, and in a networked system operational balances (inputs and outputs) must be maintained.

In a networked system a new layer of complexity is added. Networked systems, whether power grids, telephone systems, or transportation systems, have a layer of behavior ("network performance") that is independent of and constrains the underlying technology. If not understood and planned for, network performance can cause unexpected results. A snowstorm in Seattle causing flight delays in Miami (due to gate holds and shortages of aircraft) is but an obvious example of how an operational anomaly can ripple through an entire network. Engineering supplies a well-developed, if specialized, understanding of network effects, including queuing behavior, self-stabilization, tracking errors, oscillation, and hysteresis.

Attempts to maintain these systems using market mechanisms create periodic shortages (such as flight delays) and local catastrophes (such as accidents). Although in the long run a market will balance itself, the public has concluded that periodic shortages and local catastrophes are an unacceptable price for the freedom of the market in large-scale technological systems.

Development of the regulatory mechanisms and representations that maintain technological systems has not been commensurate with their growth in scale and coupling. Global aviation, a large-scale technological system spanning multiple national borders, is regulated (although this is too strong of a word) by various bodies of the United Nations, by multilateral arrangements among airlines, or by the dominant power of the leading aircraft manufacturers. A small illustration of the opportunities and limitations of each of these is appropriate.

An affiliate of the United Nations, the International Civil Aviation Organization (ICAO), is responsible for negotiating agreements among 185 national regulatory authorities on subjects as diverse as communication standards, navigational beacons, runway lighting, and airport facilities. ICAO has no enforcement authority, and its officials, some of the most prestigious figures in the aviation world, rely on persuasion to "harmonize" practices among ICAO members. The difficulty of their task can be appreciated by the fact that the promotion of Standard Aviation English (SAE, a uniform phraseology for communication among pilots and between pilots and air traffic control), while accepted in nearly all developed countries, has not been adopted by airlines in the United States.

Another regulatory mechanism that has arisen, although not proffered as such, is the rise of multicarrier alliances. An "alliance" is a branded agreement among three or more carriers to share routes, capacity, and other resources. The two leading alliances are Star Alliance (United, Air Canada, Mexicana, Air New Zealand, Ansett Australia, SAS, Lufthansa, Thai Airways, Varig, All Nippon); and One World (American, British, Canadian, Qantas, Finnair, Iberia, Cathay Pacific). These offer travelers a seamless transportation experience around the globe. Some of the functions and resources that are being combined or integrated within alliances, or at least under discussion, include:

Code sharing: passenger bookings

Flight crews: interchange between airlines

Maintenance facilities: aircraft repair in remote locations

Passenger awards: frequent flyer miles

Publicity and promotion: unified alliance image

Interchange of aircraft: "hull-swapping"

Financing and equity stakes in partners

These developments bespeak a de facto consolidation and regulation of an international industry, even if de jure international consolidation and rationalization are precluded by the national pride and civil statutes of the world's civil aviation authorities.

The third source of dominant influence, and hence regulation within the industry, is the aircraft manufacturers. When Boeing or Airbus deliver an aircraft, they also deliver a set of procedures ("manuals") for operating and maintaining the aircraft. They may also deliver a set of relationships ("financing") that enable the lease or purchase of the aircraft. They also implicitly deliver a set of cultural assumptions ("design philosophy"), of American or European origin, regarding the appropriate relationship between flight crew and flight technology. For example the color red, a standard for alarms, has quite different meanings in Western and Asian cultures.

What these three regimes (ICAO, alliances, aircraft manufacturers) have in common is that they are attempting to regulate behavior within a large-scale technological system spanning all the major cultural regions of the world. To the extent they are successful, ICAO, the alliances, and the manufacturers themselves become the cockpit for the negotiation of cultural differences among the nations and peoples that make up commercial aviation around the globe.

To summarize provisionally, the large-scale integration of civil aviation is freighted with cultural practices and assumptions whose acceptance and comprehension in any part of the world is not to be taken for granted. Culture here is a far different matter from questionnaire responses or national stereotypes: culture here is a matter of collective representations and negotiated differences that resist fixed or authoritative characterization. Authoritative efforts to fix (mend, correct, neuter, hypostatize) cultural differences elicit resistance, whether in the rejection of CRM or SAE, or in protests over the design of autoflight controls.

Toward an Anthropology of Large-Scale Representations

Technological systems have grown in scale more than have the social representations that maintain them. These representations—"culture" or "cultures"—within socio-technical systems are no less a part of the system dynamics than are mechanical components or information resources. The culture of a large-scale technical system supplies the resources for sensemaking needed by those involved in the system and the symbols of legitimation for those who govern the system. When those implicated in the system are unable to make sense of the system or its behavior, catastrophe results. To the extent that those implicated in the system are able to stabilize their representations of the system, normal operation can go forward.

By stabilization of representations I understand not uniform comprehension or consensus, but shared awareness of basic conditions and constraints. For example, some of the greatest risks to safe flight today are from the passengers. As broader segments of the public fly, passenger understanding of the risks of flight has declined. Numerous incidents of passengers jeopardizing safe flight, whether by carrying flammables in the passenger compartment, opening luggage bins during landing, operating cell phones in flight, or threatening crew ("air rage") are well documented. On a larger scale, the differential operational standards in diverse world regions creates unique risks for international flight.

Passenger flight in the third world is a much different matter from the first world. Equipment is older, the technology is imported, there may be less emphasis on passenger comfort and convenience, and air traffic management facilities are weak or nonexistent. As a consequence, accident rates in Asia, Africa, and Latin America are much higher than they are in Europe or North America. Within the industry the usual explanation for this is simply that the third world has not yet "caught up" to the industrialized world (Thornton 1997; Saxer 2000), whether in terms of training, air traffic management, or ground facilities. An alternative view would suggest that in today's world system, the third world will always be a technological periphery and that the higher accident rate in third world aviation is the dark side of affordability, comfort, and convenience of first world aviation.

These shared understandings are not matters that can be conveyed through a public address announcement at the beginning of a flight, in an Airbus service bulletin, or in an ICAO circular. These representations are cultural, that is, a matter of negotiated understandings of context and self and other. Although anthropology supplies a supple and subtle comprehension of small-scale representations, it is only beginning to similarly comprehend the large-scale representations that structure large-scale technological systems (but see Douglas 1990, who first, I believe, noted this issue).

Anthropology's strengths lie in ethnographic observation, contextual understanding, and responsibility to cultural differences. Together these supply an alternative imaginaire for humanity to the decomposed and retrofitted human factors that are reaching the limits of their service life.

There are a few studies of human behavior and systems pertinent to the domain of civil aviation based on anthropological principles of ethnographic observation and sensitivity to context. These studies, as described below, point to the possibility of a contextual understanding of the representations of aviation, and hence of an anthropology of large-scale representations.

An excellent example of an ethnographic study of aviation is Hutchins's (1995) cognitive account of "How a Cockpit Remembers its Speeds." Landing a jet transport involves a complex set of precise transformations as the aircraft descends, slows down, approaches the field, and changes its wing configuration to maintain stability. Wind speed, temperature,[4] and aircraft weight affect the calculations of descent profile and landing speed. Well before they begin descent a flight crew will begin planning its landing and planning the configuration of the aircraft and instrument settings to maintain a descent profile that brings the aircraft to the right place (the runway) at the right time at the right speed. As the airplane slows down and approaches the ground, the margins for error in speed, altitude, navigational track, and trim shrink. The flight crew has available multiple controls (thrusters, elevators, flaps, slats, speed brakes) to maintain the balance of speed, attitude, and sink rate: too much speed and the airplane cannot descend, or will land "hot." Too little speed, and the airplane stalls. Too much attitude, and the plane stalls; too little attitude, and it picks up speed and descends too rapidly. Too much sink rate (measured in feet per minute of descent), and the airplane crashes; too little, and it overshoots the runway. A well-planned descent minimizes the cognitive tasks of the last few minutes of a landing (which, as is evident here, are quite complex); the cognitive tasks of planning and executing the descent are distributed among the flight crew and the flight instruments. In Hutchins's account, it is not simply the flight crew but the *cockpit* (flight crew + flight instruments) that performs the cognitive tasks of planning, calculating, and adjusting flight parameters as the aircraft proceeds through its descent profile.

Hutchins emphasizes the communicative construction and self-regulation of contexts. Despite organizational ideologies that emphasize vertical control through management, lines of authority, and procedures, most behavior is regulated contextually, that is, through lateral control. Contexts contain within themselves feedback mechanisms that maintain the stability of the context. These feedback mechanisms are often subtle—in Edward Hall's term, "high context"—and discovered only through sensitive and sympathetic observation. Only after prolonged observation can one be sure if raised eyebrows, or an altered tone of voice, contain a rebuke or an approbation (i.e., negative or positive feedback).

The expression "high context" illustrates another part of this point, that contexts can be self-organizing in addition to self-regulating. Over time contexts build up repertoires of messages, meanings, and expectations that contribute to the stability of the context. Whether this is based on a "search for equilibrium" (Perin 1995:160, following Barker 1968), or a teleological result that is evident only in hindsight, is less important than the understanding that contexts tend to perpetuate themselves through their internal messages.

Linguistic and cultural insight can reveal other dynamics within a system that are often transparent from a managerial point of view. Perez and Psenka (2000), for example, apply the concepts of system dynamics and contextual interpretation to the analysis of an accident where technological complexity, breakdowns in coordination, expectations conditioned by cultural differences, and miscommunication all contributed to a CFIT, or controlled flight into terrain. In the 1995 Cali, Columbia accident, one of the more puzzling accidents in recent years, two American Airlines pilots flying an advanced aircraft progressively lost situational awareness and coordination. Miscommunication with ATC, a confusing interface for the flight management computer, and schedule pressure all contributed to a stressful and deteriorating situation. Although no close ethnographic observation was available for the reconstruction of this (or nearly every other) accident, they were able to use the familiarity of an airline captain (Perez) with operational procedures and the operational environment to reconstruct a self-reinforcing "death spiral" of rising stress, deteriorating situational awareness, and breakdown in crew coordination; one by one, corrective options were eliminated *by the dynamics of the situation* (Perez and Psenka 2000).

Studies of aviation communication provide a third area in which contextual understanding would be of value. Inasmuch as cultural understandings are negotiated through acts of communication, an appreciation of the multiple levels and layers of communication is required to construct an anthropology of large-scale representations. Most studies of communication in aviation (Cushing 1994, for example) assume a referential model of communication, in which utterances refer to an unambiguous object; any shortfall from unambiguity is considered noise or miscommunication.

An exception to the assumptions of a referential model is found in Charlotte Linde's studies of flight deck communication using both simulator studies and cockpit voice recorder (CVR) tapes. In a study of "communicative success," Linde (1988) found that mitigating phraseology (including informal syntax, informal lexical choice,[5] or third person rather than first person) was very sensitive to social rank (the distinctions among captain, first officer, and flight engineer). Mitigation also was inversely associated with communication effectiveness: the more mitigated the speech, the more frequently descriptions of topics or draft orders failed. Despite this, the flight crews using more mitigated speech were judged to be better crews. An explanation of this paradox is that mitigating behavior encodes the relational rather than the referential aspects of communication and overall contributed to the smoothing of interaction and improving of coordination among flight crew.

Referential models of communication decontextualize it. Elements of communication that define or respond to the context are ignored. Thus it was nothing but noise preceding a fateful crash, when the pilot of American 965, on approaching Cali, spoke into COM1 (the ATC channel) "Buenos noches senior" [*sic*]. From a contextual viewpoint, however, this is highly interesting: it created a false sense of familiarity with the controller. The captain of the KLM flight that crashed at Tenerife at first did not respond to an inquiry from the second officer ("Is he not clear then?"), and only when the inquiry was repeated ("Is he not clear then, that Pan Am?") did he respond with an emphatic, intimidating "Yes!" Referentially, this silence followed by a repeated inquiry is uninteresting; relationally, it suggests a breakdown in synchronization between the captain and the crew.

Any act of human communication contains multiple layers of relational meaning that are evident only in context. Teamwork among operational personnel depends on context-building and context-regulating messages that are lost in the referential model. Understanding the breakdown or collapse of such teamwork requires as much data regarding the timing, phrasing, intonation, kinesic, and other nonverbal aspects of communication. Those who have been able to reconstruct such collapse processes (Weick 1990, for example), were able to do so only by enlisting some of these types of data.

In sum, there is a tension between the decomposed and retrofitted understanding of human possibility that is embodied in "human factors," and the adaptive, self-regulating capabilities that are embodied in ethnographic observations and anthropological concepts. This tension is paralleled by the tension between the global regulation of aviation (whether from ICAO, One World, or Airbus) and the messy facts of local nuance and diversity that will continue to constitute world cultures. The observable stress placed on flying outside the metropolitan core, whether in accident rates, stressed crews, or corporate unprofitability, suggests that aviation, or more accurately aviation technology, has but imperfectly colonized the developing world.

Each of these miniaturists—Hutchins, Perin, Perez, Psenka, Linde—points us to the possibility of comprehending the representations of aviation by those whose lives are touched by flight. Operational stresses in commercial aviation today[6] reflect a fragmentation and instability of these representations. Building on the contextual sensitivity at which ethnography excels, the next step is to comprehend the representations of the large-scale mechanisms that stabilize, or destabilize, the large-scale technological system.

Postimperial Peripheries

In the last 150 years mechanized transportation and communication—railroads, steamships, buses, airplanes, along with telegraph, telephones, telecommunication, and now the Internet—have altered the personal and societal radii that once defined human scale and hence the frontiers of anthropological understanding. "Anthropological" is used here in a classic sense of concern with the nature of humankind, an enterprise far more urgent than simply poking around the dusty attics of the mansions of humanity. Anthropological theory has long since abandoned the assumption of clear societal or cultural boundaries, although anthropologists still often seek (or yearn for) out-of-the-way, cobwebby places to do their fieldwork. Assumptions about locality and rootedness still insinuate their way into anthropological writing, even if they are not specifically acknowledged: ample evidence of this is found in the concept of "a culture" that can be identified with a set of spatial coordinates. A more accurate depiction of what was formerly called "a culture" would be a fluid assemblage of cultural elements, negotiated with neighbors and mutable according to shifting political strategies.

Aviation, along with telecommunication, has fundamentally altered the moral interconnectedness of this world. A hundred years ago mothers could remind their children of the starving masses in Asia, encouraging them to finish their meals; Christian missionaries might begin a palliative relief effort, feeding a few thousand. By and large, however, distant wars and famine posed little threat except possibly to colonial trade concessions.

The 20th century was the period in which the world changed from agricultural production and loosely articulated village life clustered around scattered cities to an interconnected, industrialized organic whole. Technologies created in San Jose are quickly adopted in Mysore, and purchasing decisions in Little Rock create layoffs at clothing factories in Djakarta. Skirmishes in the Gulf of Yemen tax the pocketbooks of SUV owners.

Trade and technology structure the relationships among regions and nations. Trade relationships involve the movement of goods and are subject to constraints of geography; technological relationships involve the movement of ideas and are subject to the constraints of knowledge. The resulting prosperity may be less evenly distributed than the prior sufficiency, and the global system may be living on the borrowed time of resource exhaustion and environmental degradation. Otherness and difference are less associated with space and place than they were 100 years ago. The technologies of transportation and communication are both bringing the world together and creating new divisions within it.

A fundamentally new division within a world constructed by transportation and communication networks is the decomposition of humanity into its constituent parts for better adaptation to the engineered environment. The entire disciplinary confederation of "human factors" rests on the premise that human entities, whether individual lives, groups, or communities, can be decomposed into elements for purposes of tuning a sociotechnical system. In so doing it ignores, or rather negates, the observations made here concerning the self-organizing and self-regulating capabilities of contexts. The tension between self-regulation and external control is not a new story: in aviation it is dramatically framed, due to the operation in a hazardous space, the physical isolation of critical contexts (the flight deck, the traffic control center), the formalization of external control (ATC, SOPs), and the disastrous results of violating the balance between the two.

A unique characteristic of civilizations is that they are defined by their technological legacies. In contrast to earlier societies, which had mastered elaborate techniques, civilizations are at the mercy of technological legacies having roots far deeper than any person's life span. Into these legacies are coded massive arrays of representations of occupations, rituals, consumption, and authority. Sometimes this coexistence is as supple as a smooth leather glove; at other times it pinches like a cheap pair of shoes. In ways that earlier toolkits were not, this technological legacy is beyond the grasp of any individual citizen or groups of citizens, a fact that at times makes it seem out of control.

Catastrophic failures, such as the crash of a 747, define the limits of a civilization, the coexistence of a society and its technological legacy. Generically, catastrophic failures occur when one group has designed or deployed a technology that another group is ill-prepared to use, or when a group is too boldly experimenting with a technology before it has accumulated sufficient experience to have tacit knowledge of the technology's limits of safe performance. In most cases what appears to be a technological failure is in fact a social failure organized around a technological nexus: an escalating system failure that the users and managers failed to notice or contain.

Even as industrial transportation and communication are erasing the old borders of the world, they are creating new frontiers within it. On the technological periphery successive waves of discontinuous innovation create successive threats for operational balances. The resulting quotidian stresses of overworked crews, abused equipment, and ill-treated passengers are so familiar as to be unremarkable; only the occasional punctuation of a crash reminds the public that aviation on the periphery faces an unfamiliar set of difficulties.

A contemporary issue in anthropology and development theory is the extent to which communities on the capitalist periphery have the capability to organize their own sufficiency, and the extent to which this capability is undercut by national governments and global institutions. Global institutions undercutting self-sufficiency on the capitalist periphery begin with multinational corporations and include the World Trade Organization and international relief agencies. A similar effort at understanding has not yet been made for the technological periphery.

Frozen in the amber of the academy, anthropological theory (as contrasted to the day-to-day efforts of ethnographers and practicing anthropologists) has not yet caught up with the new global structures of technological marginalization. Although world-systems theory (Wallerstein 1974), with its insight into economic marginalization, is well established within anthropology, the reproduction of a technological periphery is scarcely commented on. Core-periphery and metropole-hinterland relationships once associated with geographic distance are breaking down, only to be replaced by relationships of technological distance and dependence. Communities find their integrity and security under assault from technologies that offer the promise of escape from economic marginalization.

In its early days anthropology focused on the totality of humanity, both in its shared historic evolution and in its contemporary diversity. As naïve evolutionism was discredited, and as the colonial enterprise insisted on being informed about hinterland peoples, anthropology turned from the study of humanity to a comparative sociology (and comparative economics and comparative political science and comparative humanism) of indigenous peoples. In the contemporary engineered world the indigenes are the "users," and the manipulation of their "human factors" is likewise a colonial enterprise. The border phenomena of an industrial civilization include environmental degradation, economic dislocation, and industrial accidents. These are phenomena not only of a capitalist world system, as real as that is, but also of a process of technological marginalization, which in the engineered world is creating new forms of dependence and insecurity.

Notes

[1] A commercial airlines must balance profitability, safety, and passenger comfort and convenience. Both safety and passenger comfort are expensive and eat into profits. Without this balance, the airline dies.

[2] Regarding the problem of aircraft systems adaptation, obviously in some ways aircraft have been adapted to human requirements. Both the pressurized cabin and the on-board lavatory are clearly adaptations to physiological requirements. On the other hand, the precursor to the pressurized cabin, the oxygen mask, is clearly an adaptation of the human body to the flight environment. Aircraft, human bodies, and human social systems have sets of operational boundaries, which are sometimes discovered only by testing the boundaries ("pushing the envelope") Only when one system approaches the boundaries of the other is it required to adapt. As the pressurized cabin and oxygen mask illustrate, the sequence has been flight environment (altitude > 14,000 feet) led to bodily adaptation (oxygen mask); social development (commercialization of flight) led to mechanical adaptation (pressurized cabin). In the 1940s the further growth of the commercial aviation system was limited by the unwillingness of passengers to wear oxygen masks (an example of what Hughes cite calls a "reverse salient"), thus leading to the requirement for a pressurized cabin.

Regarding more general of sociotechnical adaptation, concern over the mutual adaptation of humanity and technological systems again has been a predominantly postwar phenomenon. Early concerns with "joint optimization" of "sociotechnical systems" (Trist, Susman, and Brown 1977) and "adapting men to machines" (Bell 1947) were succeeded by disillusionment with industrial technology in general. Although every industrialist learns from competitors, there has yet to be a productive dialogue between industrial technologists and their critics.

[3] The space provided here is neither available nor appropriate to discuss the various relationships of psychology, sociology, anthropology, and political science to positivist epistemology. It will suffice to note that the lack of engagement with this issue is a major contributor to the maintenance of cordial relationships within academic departments.

[4] Landing a small aircraft in an urban airport on a hot summer day can be especially trying. Updrafts from the city pavement cause the plane to rise and sometimes defeat the pilot's best efforts to descend. Sometimes nearing the surface a "ground effect" will cause the plane to seemingly float above the runway, even with the engines shut down.

[5] So that the point is not missed, a pedantic elaboration should make clear that "informal" means unauthorized or nonstandard, i.e., contrary to the provisions of Standard Aviation English.

[6] The chronic unprofitability of airlines is chronicled by Petzinger (1995). Stresses on crew are evident in the labor unrest in the industry. Passenger stress has become a subject of federal legislation. However, no one has yet drawn the connection between these stresses and the inherent nature of a large-scale sociotechnical system.

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