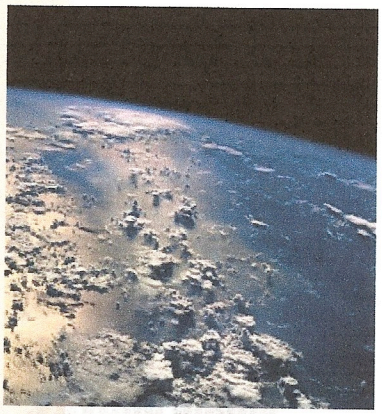
The Human Factors Organization in Commercial Space



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The initiative to return to the moon, the impending retirement of the space shuttle, and the proliferation of private space transportation companies have caused fundamental changes across the aerospace disciplines. The dawn of commercial space is at hand, and the race to capture the best model for a commercially viable manned space program has begun. An ironic reality is that the original generation of space manned systems managers is nearing retirement. The manned systems design era waned at the conclusion of the design of the International Space Station (ISS), and through the beginning of the 21st century, when operations and construction were the focus of manned initiatives such as the shuttle and ISS. The commercial manned space industry was born with a shortage of experienced specialists in human factors, the key discipline.

Why include dedicated human factors expertise?

As commercial space organizations and business opportunities multiply, decision makers will increasingly see the need to evolve their organizations from early growth phases to configurations that build long–term competitiveness. They will find that, as their customers learn their markets, suppliers will need the technical power provided by a lean, but specialized human factors team.

Some rising commercial space organizations may take minimalist approaches, building their staffs without dedicated human factors expertise. In the past decade many technical college curricula have included awareness of human/machine interfaces. Their graduates are more aware of the concepts of human factors than ever before. But only "awareness" will not suffice in the new market. The pioneers of manned technology in World War II, the Cold War and early NASA space programs learned a lesson: the best way to address the complexities of manned systems and increase total system performance is to use human factors specialists.

The reason lies in the fact that human factors issues are embedded in all the technical domains that comprise a manned space program. To varying degrees, all manned space programs include the following communities:

- Astronauts
- Passengers
- Engineers
- Procedure developers
- Government regulators
- Maintainers
- Unions
- Manufacturing operations

The people who deal with human factors in these organizations are educated in their fields, but are typically skilled in human factors as a secondary or acquired capability. There are several synergistic functions performed by human factors specialists in this scenario. Their key responsibility is the integration of the human factors aspects of other domains. Their independence from other specialties provides human factors specialists a perspective from which they can ensure that human/machine interfaces are efficiently addressed across the program.

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Human factors specialists also provide the ability to interpret regulations and customer requirements. Human factors requirements are usually expressed in terms that are familiar only to people who have been exposed to them in specialized college curricula. Translating requirements into terms that can be directly utilized by a design organization is a practical, but critical component of the business of design.

Design organizations frequently encounter gaps in the guidance provided by regulations or customer requirements. In these cases, the program relies on human factors specialists to use their research and development skills to fill the gaps with derived requirements.

Another powerful contribution made by human factors specialists is the development of tools, that, when deployed by generalists across the program, increase their level of de-facto human factors expertise. Examples of this are digital human modeling and other software systems that are developed and trained by anthropometrists, but applied by engineers. The force multiplication effect of tools is one way that efficient human interfaces can be assured using a small team of specialists. Proper training and support of the tool users, provided by the specialists, is still required to prevent issues that develop due to over-simplification of subtle human interface concerns.

Human factors analysis is required in the assurance of maintainability and produceability. In addition to traditional physical access and safety analyses, the human factors specialist can play a critical cross-disciplinary oversight role in the effective implementation of PLM (Product Lifecycle Management). Digital human modeling provides the virtual human that is used in conjunction with virtual hardware concepts to verify maintenance access and assembly sequences. For PLM to be effective a viewpoint that is independent from any one aspect, such as wiring, plumbing, or structure, is required. An independent perspective helps ensure that all interferences are resolved virtually, before metal is cut. In addition to mechanical interferences between parts, the program must resolve conflicts between parts and (1) humans, (2) paths required to remove, replace, and access components and (3) paths required to operate the tools required for maintenance and assembly tasks. Tremendous impacts on schedules result from after-the-fact discoveries that integration or assembly is impeded by the arrangement of components or human access problems. The reflection of such conflicts through the supply chain can cause catastrophic rework for entrepreneurial organizations. Working in conjunction with PLM administrators, human factors specialists can provide independent checks to ensure sufficient space for manned operations is "designed in" concurrently with the hardware.

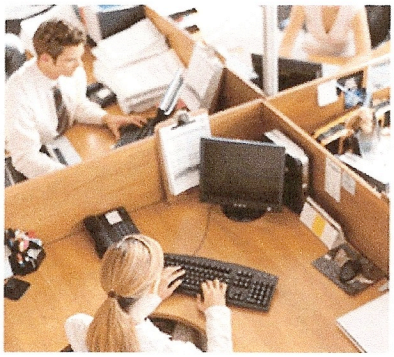
Human factors specialists provide advocacy for human operators that extends beyond the design of space vehicles. Occupational safety in manufacturing is another of the skill sets possessed by human factors specialists. Human factors experts can also apply operations analysis methods in developing efficient fabrication, assembly and integration procedures.

A common role of the human factors specialist in production is Management Representative in Safety Management Systems. System Safety, following the global trend toward ISO-based quality management systems, utilizes the specialized knowledge and coordination skills of the human factors specialist. Risk management, corrective actions, management review, requirements management, employee training, auditing and policy development are among the responsibilities of safety Management Representatives. As commercial space organizations continue on their path to globalization, the "management system" approach to safety can be expected to grow.

Commercial space systems have a bright future. Many of the technological marvels they will contain can now only be imagined. It is certain, however, they will depend on advanced digital displays, complex human/computer interfaces, and 0-g laboratory and habitation hardware. The success of these innovations requires successful integration with the human user.

Human factors specialists earned their way to positions that influenced design and contributed as much as engineering and astronaut communities to the successes of early space programs. Considering the competitive pressure from the world's changing space community, today's managers cannot afford to forget that human factors is a key specialty in manned space activity.

The new human factors organization



What is the model for the commercial space manned systems organization of the new era? The previous models of manned systems organizations were either (1) government R&D groups (2) contractor proposal teams that were expanded to work the contract, or (3) government contract monitoring staffs. Now, managers of the new generation of manned space flight are formulating models for the commercial space human factors group that may resemble the 20th century approach, but will address 21st century economic realities.

The popular definition of "human factors" has changed since the last major manned design program. While human factors engineers in the past took a generalist's approach to human/systems engineering, today's "human factors" graduates are more likely to be specialized in software usability, with an emphasis on web application issues. This is a vital part of today's society, and few human/machine interfaces do not include software. But the managers of manned space flight organizations are finding they also need the broader human factors engineers of the Apollo / ISS days.

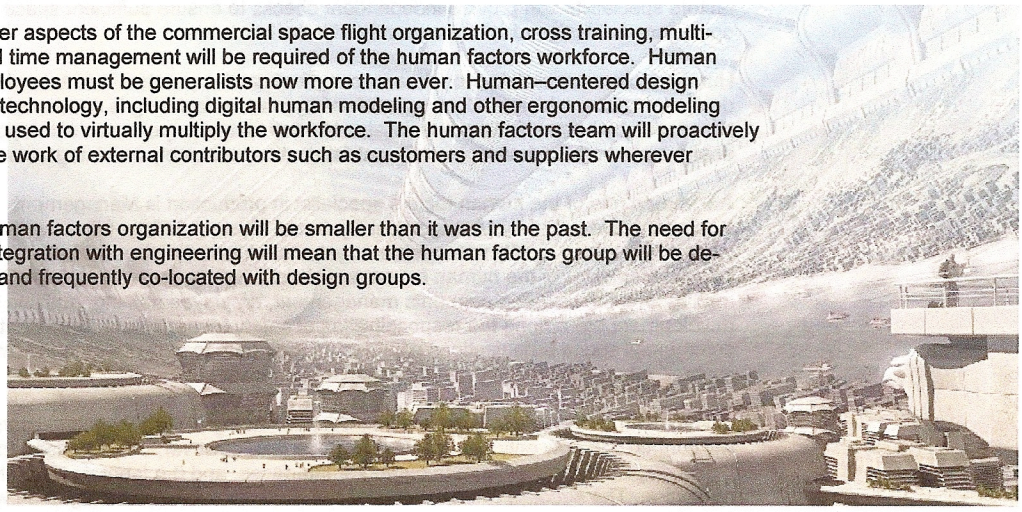
The new organizational model will evolve from the traditional department, retaining successful features that are relevant to the private sector and very likely borrowing proven concepts from aviation and manufacturing. In design, for example, launch vehicles must accommodate the anthropometric extremes of large civilian populations, not smaller military population ranges. Body restraint systems and manual controls that were custom-designed for individuals won't satisfy the requirements of commercial vehicles that are designed for larger populations of users. Controls, displays and human/computer interfaces will need

to be easier to use than earlier systems. Developers of these interfaces will assume that operators of mature commercial systems are not as highly skilled or motivated as their pioneering predecessors. The comfort and aesthetics of the commercial crew environment will also have a higher priority than ever before.

The commercial environment will have a major effect on the structure and operation of the human factors organization. Project management concepts will be emphasized to ensure that the costs of effective human integration are controlled. Concepts from LEAN and Continuous Quality Improvement including waste reduction, value stream mapping, and employee empowerment will be applied in the operation of the team. Rapid prototyping and the creative re-application of proven design concepts will augment research-driven approaches. Technical sub-specialties will be carefully managed to eliminate misdirected or duplicative effort. All human factors activities will be transparently linked to contract deliverables to increase budgeting accountability.

As in all other aspects of the commercial space flight organization, cross training, multi-tasking, and time management will be required of the human factors workforce. Human factors employees must be generalists now more than ever. Human–centered design automation technology, including digital human modeling and other ergonomic modeling tools will be used to virtually multiply the workforce. The human factors team will proactively integrate the work of external contributors such as customers and suppliers wherever possible.

The new human factors organization will be smaller than it was in the past. The need for complete integration with engineering will mean that the human factors group will be de-centralized and frequently co-located with design groups.



The new roles of the human factors specialist

As in commercial aviation, a strong focus on safety will be driven by the bottom line. Commercial manned space systems can't be sold if the market's threshold of perceived or real risk is exceeded. Safety will always be a top priority of the commercial space human factors organization, but forces of the marketplace will also require human factors specialists to understand (1) maintainability, (2) produceability, (3) rapid, digital design methodologies, and (4) the development of space and ground procedures.

Design for maintainability will be one of the top priorities. The facilities and vehicles produced by commercial space organizations will be designed for an increasingly pragmatic customer. While they will initially be used for research and testing applications, the missions will ultimately be driven by the need for return on investment. As a result the system will differ from the International Space Station, a custom-designed laboratory manned by astronaut researchers. The new model will be more similar to luxury tourism or offshore drilling rigs manned by highly skilled blue-collar technicians. In either case, compared to traditional astronauts the new end users will be less technically accomplished, less famous, less motivated, and less likely to adequately maintain facilities that have not been specifically designed for easy maintenance. These users will have a significantly lower tolerance for discomfort, safety risks and unnecessarily complex procedures.

Manned systems departments will also need an increased sensitivity to produceability issues. In order to accomplish more with fewer resources, the human factors staff will be required to understand manufacturing methods to a larger degree than ever before. LEAN, ISO, and Continuous Quality Improvement concepts will join user-centered design in the toolbox of the commercial space human factors staff.

Integration with the engineering design team will be essential to the success of the new human factors team. For this reason, the human factors organization will include a larger proportion of engineers and industrial designers than was typical of traditional life sciences-based organizations. Like their engineering counterparts, human factors specialists will creatively apply off-the-shelf concepts in new configurations to lower costs and raise levels of reliability and maintainability. A bias toward design will be essential to effectively support the organization's implementation of rapid prototyping and PLM techniques. Knowledge of these technologies must be augmented by expertise in deploying the technologies in large, multidisciplinary organizations.

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Manned space operations development will require the expertise of the astronaut community to provide experience-based inputs. But for operations that are beyond the experience of current astronauts and systems, managers will rely on methodologies that are used in planning industrial processes. The human factors specialist will be expected to translate terrestrial industrial method design into its extra-terrestrial counterpart. This frequently involves hands-on, "get dirty" pragmatism in addition to analytical or simulation-based approaches.

Who, and where, are the human factors specialists?

To meet the daunting requirements of the commercial market in the new era of economic austerity, human factors will require representation from a broad cross-section of functional disciplines. Among them are:

- Requirements identification, interpretation, derivation and compliance assurance
- Environmental control and life support systems
- System safety
- Operations and manufacturing procedures development
- Error and workload analysis
- Anthropometry / digital human modeling
- Digital display design
- Software usability
- Structures and furnishings design

The academic disciplines that must be represented in order to provide expertise in the functional areas listed above include:

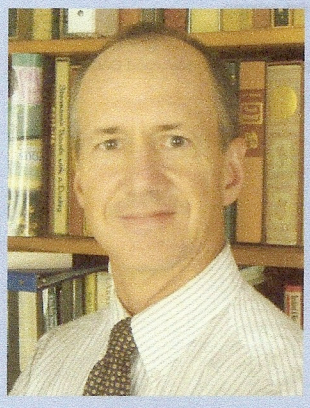
- Human factors engineering
- Engineering psychology
- Ergonomics
- Work physiology
- Industrial or product design
- Safety engineering
- Aerospace medicine
- Computer science
- Operations management

Finding engineers or psychologists who are trained in several of these disciplines is a challenge. But there are ways to find these skills and, if necessary, "grow your own" in time to stay ahead of the approaching wave of manned systems design activity.

Where will 21st century commercial space managers find these unique individuals to fill the void left by the retiring Apollo generation? Some of the software usability specialists of the dotcom era are good candidates for the human engineering generalist job. Some candidates work for major government contractors and may welcome opportunities to move into private industry. Some human factors specialists who have moved to other functions in aerospace organizations may be interested in returning to their original field. Some candidates in research organizations may want to apply their work to commercial systems. Others may be students, specializing in software usability, possibly unaware of the breadth of the human factors discipline.

Experience in a variety of programs has also proven that human factors experts can be created internally. Even if they don't have the perfect mix of degrees or experience, effective manned systems contributors can result when managers (1) employ proper career development methods and (2) provide appropriate analysis tools.

The reorientation of the global space community has happened. The future of space activity will be manned. The challenge for the growing commercial space organization is to find the resources and build teams that are more effective than that of their competition. Management insight and an understanding of human factors are the keys to capturing leadership in commercial manned space.



Con Underwood's consultation in human factors and safety engineering has boosted human productivity and cut accident rates in a broad array of design and manufacturing organizations. His career spans thirty years of innovation in advanced manned systems including crew systems design for NASA's International Space Station, commercial aviation design and FAA certification at Boeing. His accomplishments include managing the development of award-winning CAD human engineering tools, revolutionary mapping tools for the energy industry, and progressive safety and environmental management systems. Working with organizations such as SAE, OSHA, FAA and the developers of NASA-STD-3000 he devises enlightened approaches for compliance with current human-machine interface requirements. In addition to engineering classroom instruction he has trained hundreds of manufacturing and utility employees in the automation of manual tasks, safety, environmental, and ISO compliance. His investigations of industrial safety incidents drive down accident rates, triggering insightful procedure revisions, relevant employee re-training and discerning corrective design solutions. Con holds a Master of Science degree in Human Engineering and Ergonomics from the school of Industrial and Systems Engineering at The Georgia Institute of Technology. His Bachelor of Science degree is in Industrial Design from The Georgia Institute of Technology.

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