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AEROSPACE ARCHITECT OCCUPATIONAL SPECIALTY FOR NASA

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ABSTRACT

This essay presents a proposal to establish an AeroSpace Architect specialty within the Federal occupational classifications. It would benefit NASA, as it would provide a clear position description for architects working within the agency's program, and thereby make the best use of their abilities and skills.

Architects in NASA serve in several occupational classifications. There is an "Architecture Series," which deals strictly with Earthbound facilities, and the "Experimental Facilities Development" Series, which can cover much of the same subject area, but from a predominantly engineering perspective. Under its agency prerogative to create specialty positions unique to its needs and mission, NASA developed the "Aerospace Technology" (AST) rubric. Under this rubric NASA created several positions in which AeroSpace Architects may serve. These positions include Crew Station Systems, Environmental Control Systems, "Project Management" and Flight Systems Design.

This essay identifies two equivalencies between the private practice of Architecture and AeroSpace Architecture within NASA. These equivalencies encompass the project development sequence and the career ladder. The discussion also addresses two controversies among AeroSpace Architects: the role of professional licensing for the practice of architecture and the role of the doctorate in architecture as a research credential. These issues contribute to the ways in which AeroSpace Architects work. Finally, this essay proposes a new occupational specialty position for the NASA AST–AeroSpace Architect, and includes a detailed description in the APPENDIX.

INTRODUCTION

AeroSpace architects contribute to NASA programs in the conceptualization, design, development, construction and integration of airborne science platform aircraft, space habitats, space stations, lunar and planetary bases, and terrestrial facilities to support specialized research and space-related functions. For the purpose of this essay, the definition of AeroSpace Architecture is ***the design of airborne or spaceborne living and working environments, structures and configurations***. The airborne operational environment is severely unforgiving of design errors or failures, and the space environment is even less forgiving. This discussion for the AIAA Space Architecture Symposium addresses only the space environment, but the airborne environment brings to bear comparable considerations.

The two main constraints on which this definition stand, and indeed which make it possible at all, concern the hostile space environment and human requirements for spaceflight and space habitation in that environment. AeroSpace architecture must overcome the threats to health, life and safety from the extraordinarily hostile environment. These extreme environmental threats include vacuum, radiation, micrometeoroids, space debris, extreme diurnal, orbital and thermal cycling and altered gravity regimes. To meet human requirements for crew health and safety, AeroSpace Architecture must take into account the vast number of considerations for protecting the crew and using habitability design to support them in the living environment and enhance their productivity in their working activities.

The Profession and Discipline of Architecture

The profession of architecture has been serving human civilization for several thousand years as the "second-oldest profession." Architecture was one of the first disciplines to develop specialized professional education. The training of architects is uniquely broad and integrative when compared to the other arts and to engineering and the sciences.

The training of the AeroSpace Architect contributes to four main professional attributes:

1. Design innovation that at its best is research-based,
2. Design integration of all the design disciplines,
3. Design Method, and
4. Spatial Conception in Three Dimensions

If there is one distinguishing feature that separates the *practice of AeroSpace Architecture* from the *practice of terrestrial architecture*, it is that AeroSpace Architects depend much more extensively on new and pioneering research to understand both the space environment and the human requirements of the users of space habitats. In this regard, an AeroSpace Architect must become a critical consumer of design research.

Design Innovation in AeroSpace Architecture

Thus, innovation in AeroSpace architecture derives from a unique fusion of research and design. Unlike some prominent terrestrial architecture, innovation does not come from an architect having a wild and crazy new formalistic idea, and then hiring an engineer to make it stand up. On the contrary, the AeroSpace Architect must become thoroughly versed in finding and interpreting all the relevant research, and integrating the necessary engineering into the project. In the technical and legalistic sense of a patent application, innovation requires three properties: novelty, utility and "buildability." More specifically:

Novelty requires that no one has invented this design previously. Changes to shape, size, scale, proportions or color do not qualify as novelty.

Utility requires that the design or invention can afford some beneficial use – it is not just a sculpture or other work of art.

"Buildability" requires that a craftsman "skilled in the art" can make the design product, and that the craftsman can make it out of materials that exist and have the necessary properties.

Given these criteria, it becomes evident that in the field of AeroSpace Architecture, not every new design project will meet the criteria of innovation or invention. A project may be a fabulous, fantastical, visionary concept -- it may be an awesome dream -- but if it does not meet these criteria it is neither innovative nor inventive. It may be a beautiful, breathtaking work of art, but it is not AeroSpace Architecture unless it meets the definition and supporting criteria at the beginning of this introduction. Having stated these limitations, there remains an infinite scope of opportunity for design creativity in AeroSpace Architecture.

Design Integration in AeroSpace Architecture

The second attribute of AeroSpace Architecture is the architect's role as a design integrator. The trained architect's understanding of how all the other design disciplines must fit and work together is a particular capability and skill that AeroSpace Architects bring to the design team. Walter Gropius, a founder of the Bauhaus School of Design in Dessau, Germany and later Chair of Architecture at Harvard University, described this synthesis of training and design profession:

> 1. The architect is to be a co-ordinator— a man of vision and professional competence—whose business it is to unify the many social, technical, economic and artistic problems which arise in connection with building.
>
> The architect has to recognize the impact of industrialization and should explore the new relationships dictated by the social and scientific progress. (Gropius, 1962, pp. 55-56).

Alice Eichold, an architect who won a NASA Graduate Fellowship for a space architecture master's thesis offers this insight into the particular value of a professional architectural education for understanding the total scope of design:

> What I value about architectural education is the experience of lots of students solving the same problem in different ways. All get to see the results and to understand not just one solution but a wide range of solutions, from good to bad and understanding why.
>
> Nothing in engineering compares to our role as expert generalists, because that is what we are. But that is also what system engineers think they are. However, most of them were expert specialists before they became expert generalists, and are biased (Eichold, 2002, March 21, personal communication).

The bias to which Eichold refers is the predilection to reduce everything to numbers, the mechanistic attitude that regards the only questions worth answering are those that can yield up deterministic, quantitative answers. The system engineer can then manipulate these numbers in many ways utterly removed from the actual design process or product. Often these numbers feed into abstract trade studies at the cost of losing sight of the totality of the design project. The architect's orientation focuses instead upon the totality of the design outcome, in all its implications and consequences.

Design Method in AeroSpace Architecture

In this same passage, Gropius continues to describe the profession. He emphasizes the holistic aspect of architectural education, with the clear implication that this training must carry on into professional practice.

> 2. In an age of specialization, method is more important than information. The education of an architect should be concentric rather than sectional. In essence it should be all-inclusive . . . (Gropius, 1962, pp. 55-56).

What underpins Gropius' argument about method is that for the well-trained architect, design is a self-conscious process that architects are aware that the way they design will influence the product of the design process. For the practice of AeroSpace Architecture – as for terrestrial architecture – the recurring question with each project is which method is best suited to produce the desired results. (Broadbent, 1981; Cross, 1984). These questions concern who provides the requirements, who evaluates the requirements and on what basis, who does the design, who participates in the design process, and "who decides the outcome?" (Rittel. 1972).

Beneath these methodological problems is a more fundamental question of value: who does the architecture serve – the people, the machine, or "the system." It is surprising now to recall that when this issue of human-centered value arose in the late 1980's to 1990s, it was a somewhat revolutionary assertion for the engineering community, but now it is widely accepted, if not always understood (Rouse, 1993). There was no such revolution necessary for architects who have always focused on the human living and working environments to serve the occupants (within the limits of resources and client expectations).

Spatial Design

In the Renaissance, three-dimensional space because the "language of architecture," Gropius shows that the synthesis of design innovation, design integration, and design method culminates uniquely in the three dimensional, spatial development of the designed environment, products, and projects.

> 3. Three-dimensional conception is the basic architectural discipline . . . (Gropius, 1962, pp. 55-56).

Architects train intensively in the three-dimensional discipline, so they learn to create in spatial conception. The preeminent role of spatial cognition gives architects the ability to handle the three other attributes – especially the demands of three-dimensional physical integration of design. This spatial cognition is particularly valuable when working out the problem that the electrical engineer's conduits do not need to penetrate the mechanical engineer's ducts; and the mechanical engineer's ducts do not need to disrupt the structural engineer's trusses; and so on . . .. The architect as integrator routinely resolves these conflicts by spatial cognition that otherwise may seem insurmountable to the stakeholders in the allied disciplines. In the design of a space module for altered gravity environments, this spatial cognition can be especially useful for the immense complexity of the habitat outfitting (cables, ducts, stand-offs, racks, panels, partitions, etc).

Aerospace Architects in NASA

NASA employs architectural graduates in several capacities. At present, there are licensed "facilities architects" who work on the buildings at every NASA center. Three licensed architects work in the space program. Two work directly for NASA, one each at NASA-Ames Research Center and NASA-Johnson Space Center, plus one works for at Lockheed-Martin in Houston, in support of JSC. In addition, there are up to two dozen architectural graduates -- people with architectural degrees -- working in AeroSpace programs or research, mainly at NASA-JSC, but also at NASA HQ, NASA Dryden Flight Research Center. There are a number of architects working directly for aerospace companies, but so far relatively few working for private architectural firms who design for space. Also, there are a rapidly growing number of architects who teach at universities who are developing specializations in various aspects of AeroSpace Architecture. The main motivation for the growth of University programs appears to be the way it creates splendid opportunities to teach students how to do research. While these numbers may seem small now, they represent a remarkable potential for new directions for the architectural profession.

All the people working in AeroSpace Architecture within NASA have faced difficult career choices within the existing Office of Personnel Management (OPM) occupational classification system. At present, architects in NASA serve in several occupational classifications. There are two OPM general schedule classifications: "Architecture Series", which deals strictly with Earthbound facilities, and "Experimental Facilities Development Series" which can overlap "Architecture" very closely where research and laboratory facilities are concerned. NASA developed its own Aerospace Technology (AST) series, which includes the AST–Crew Station Systems, AST–Environmental Control Systems, AST– Flight Systems Design and even an AST–Project Management series. Insofar as the author can determine, NASA AeroSpace Architects have worked under all these specialties except for the straight OPM "Architecture Series." TABLE 1 shows the current occupational specialties for AeroSpace Architects, except for the AST-Project Management, because it is not defined under either OPM or NASA guidelines as a design position.

While each of these classifications serve their intended purposes – to undetermined degrees of success -- none of them serve the purpose or needs of AeroSpace Architecture. The problem that confronts the NASA architects working on AeroSpace Architecture is that without a clear position classification for what they do and the qualifications that enable them to do it, the agency lacks a baseline for the effective use of this discipline. Without this documented baseline, very few people in the agency will extend themselves to understand what AeroSpace Architects do, how or why they do it.

TABLE 1 also presents this essay's proposal to create a new AST-Aerospace Architecture specialty.

THE NASA AST SPECIALTY SERIES

Federal personnel regulations empower each agency to create their own occupational specialties that reflect most closely the actual duties and responsibilities of employees in that agency. NASA has taken advantage to create a specialty series titled "Aerospace Technology" (AST). NASA's criteria to define AST positions are as follows:

> A position is properly classified AST if it is engaged in one or more of the *areas of work* and meets at least one of the three *working conditions* identified in Paragraphs 1 and 2.
>
> ***1. Areas of Work***
>
> a. The study of space phenomena;

b. Work affected by known or unknown conditions in space or simulated space environments,

c. The science of aeronautics;

d. Application of research findings in space and aeronautics

2. Working Conditions

a. Many of these positions are interdisciplinary, bringing into play combinations of academic disciplines, which are dictated by the unique problems in the field;

b. Positions reflecting extensions of the traditional disciplines to meet the space environment or advanced flight regimes;

c. Positions wherein the duties require an understanding of problems peculiar to space and advanced flight regimes. http://www.nasajobs.nasa.gov/nscs/AST_info/AST_Criteria.pdf [original emphasis].

Two of the areas of work criteria match the discipline of AeroSpace Architecture quite well, particularly 1.b. Work affected by . . .conditions in space or simulated space environment, and 1.d. application of research findings in space. All three of the working conditions apply to AeroSpace Architecture, and indeed constitute an eloquent précis of an AeroSpace Architect's work environment.

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<u>Creating the AST–AeroSpace Architect Position</u>

At the risk of appearing self-serving, this section presents the AeroSpace Architect's perspective on the NASA System. This perspective conveys the need to afford a career path to Architects who wish to devote their talents to professional design and design research in the technical domain of

NASA. This point cannot be overstated. Frank Lloyd Wright did not become the master architect of the 20th Century in the USA by becoming a bureaucrat or an MBA manager. He achieved created many of America's most revered buildings by remaining the lead, hands-on designer for all his work.

Similarly, AeroSpace Architects who love their craft want to continue as designers throughout their career, and not be compelled to occupy non-design positions or hold non-architectural titles just to get ahead in the organization. The actual occupational specialty description modeled on the Office of Personnel Management (OPM) format appears in the APPENDIX.

TABLE 1. NASA and Office of Personnel Management (OPM) Designations For Positions Relevant to AeroSpace Architecture

NASA AeroSpace Technology (AST) Specialty Series	NASA AST Specialty Title	OPM General Schedule Series Title	OPM General Schedule Classification Series
Not Applicable	Not Applicable	Architecture	GS-0808
725-13	Flight System Design	Aerospace Engineering	GS-0861
725-16	Crew Station Systems (formerly "Manned Systems")	Aerospace Engineering	GS-0861
725-17	Environmental Control Systems	Aerospace Engineering	GS-0861
740-13	Experimental Facilities Development	Experimental Facilities Development	GS-0801
PROPOSED:			
725-18	Aerospace Architecture	Architecture	TBD

When promotion opportunities open up, the NASA system invariably measures AeroSpace Architects against engineers who may occupy the same, or similar, AST specialties. The result is that it can be extremely difficult for Space Architects to receive proper credit and recognition for their work or to enjoy promotions in the normal course of a NASA career. All to often, an AeroSpace Architect must give up being a designer or design researcher to pursue career advancement as a manager, a contract monitor, or as a paper pusher. Creating this occupational specialty for the AeroSpace Architect would afford a career path to Architects who wish to pursue design and design research in the technical domain of NASA

The purpose of creating this occupational specialty for the AeroSpace Architect is provide NASA with well trained professional designers and design generalists who can provide design leadership to understand and appreciate the "big picture." Having a strong cadre of AeroSpace Architects in NASA would provide an effective counter-balance to the many engineers who developed through a training experience of ever-narrowing specialization. It is important to point out that cultivating the AeroSpace Architect specialty is neither a substitute systems engineers nor is it in conflict with System Engineering as a discipline or a profession.

Perhaps the thorniest question is within which OPM Classification Series does it make the most sense to establish the AST-Aerospace Architect series. Both the GS-0808 Architecture Series and the GS-0861 Aerospace Engineer come with advantages and disadvantages.

The principal advantages of GS-0808 Architecture is that it is clearly a guideline for architects, so that there will not be a problem of comparing architects' work to that of engineers and that although it does not explicitly state a place for license, it leaves an opening for licensure to be a consideration as an measure of proficiency under certain benchmarks. The disadvantages of GS-0808 are that OPM defines it very narrowly and specifically to enumerate the detailed duties of a terrestrial architect. It does not offer much of an opening for aero or space architecture, nor a provision for evaluation for design research. A further difficulty is that the GS-0808 starts at the GS-9 level and ends at the GS-14 level, effectively cutting-off both the apprentice, GS-7 entry-level position, and the GS-15, top of the scale position.

The principal advantages of the GS-861-Aerospace Engineering are that it clearly applies to aero and space endeavors, and it is quite flexible in accommodating a wide variety of types of work. The disadvantages of GS-861 are that it puts architects into a comparison with engineers, and opens them up to having non-architects being given the title of "Aerospace Architect." A further peculiarity of GS-861 is that it requires only a bachelor's degree, and management can interpret it to mean that advanced degrees and professional licensure play no role, so there is no implicit credential quality control in this position series.

One further alternative is the GS-0801 General Engineering Series. However, GS-0801 offers virtually all the disadvantages of GS-861 without the main advantage of the Aerospace purpose. Therefore, it does not deserve further consideration.

Because none of these OPM GS classification series is a clear winner at this time, TABLE 1 shows the preferred OPM series for Aerospace Architecture as "To Be Decided." Hopefully, it will be possible to craft an OPM series that is a better match for AeroSpace Architecture.

Ideally, the AST-Aerospace Architecture would be based upon the professional qualifications of a degree and licensed architect, not the GS-0861 Aerospace Engineering Series. However the OPM GS-0808 Architecture Series does not really spell out those qualifications. If GS-0808 described architects in more general performance terms, it could be very valuable because NASA managers have very wide latitude in filling NASA series titles with whomever they wish. The only way to ensure that people with training and credentials in Architecture are selected for the AST-Aerospace Architecture specialty is for it to be provided in the underlying OPM standard.

The Two Equivalences

This section examines how architectural project development and career development compares to the traditional NASA system. This analysis and proposal relies in large part upon two equivalencies. The first equivalencies occur between the American Institute of Architects (AIA) project development path and the NASA System Engineering path. The second equivalence arises between the career ladder in the private practice of architecture and the federal general schedule.

NASA versus AIA Project Development

TABLE 2 shows this correlation between the NASA System Engineering Handbook (Shishko, 1995) and the AIA's The Architect's Handbook of Professional Practice (2001). As will be readily apparent, there is a very strong correlation between the project phases in each path. This correlation goes beyond the sequence of events to encompass the functional, intellectual, and professional properties of each step. There is one significant difference that does not appear: the AIA prescribes the recommended proportion of effort at each project phase to afford a basis of comparison for clients, but the NASA Handbook is silent on this consideration.

TABLE 2. Correlation of NASA System Engineering and AIA Design Project Phases

NASA *System Engineering Handbook*	American Institute of Architects *Handbook of Professional Practice*
Phase A Conceptual Design Study	1. Schematic Design
Phase B Systems Definition Study	2. Design Development
Phase C Design	3. Construction Documents
(Source evaluation)	4. Bidding
Phase D Manufacturing	5. Construction Administration
Phase E Operations	6. Post-Occupancy Support & Evaluation

NASA GS versus Private Practice Career Path
TABLE 3 shows the parallel career development paths for an architect in private practice and one in NASA civil service on the federal General Schedule (GS). This occupational specialty provides a career track for the AeroSpace Architect from receiving a bachelors degree in architecture to work as an Apprentice at the GS-7 level through the equivalent position of a senior design principal as a GS-15. The Series tracks career growth over increasing professional responsibility through these phases.

TABLE 3 presents an approximate correlation of NASA and professional practice of Architecture considerations under five criteria, each of them in its own column. The correlation is based on approximately comparable levels of responsibility and design leadership. It does not include positions with the titles "Principal" or "Partner" because those titles relate to ownership of an architecture firm, which does not come into consideration in this essay. A Principal or a Partner of a small firm may actually perform duties at many levels of responsibility, so from this point of view, it is also not distinctive.

Column 1 presents the NASA Civil Service GS grades that are open to an AeroSpace Architect.

Columns 2 and 3 show the academic requirements for NASA positions, under the Equipment Development Grade Evaluation Guide and under the Research Grade Evaluation Guide, respectively. The way to interpret the GS-9, masters degree correlation is that a masters degree is a requirement *to enter government service* at the GS-9 level, but that if an employee enters with a bachelor's degree and works successfully for a year or two, promotion to GS-9 is fairly routine. From a strictly academic perspective, the basis of this promotion is called "equivalent experience."

Column 4 shows a generic description of each level of position in architectural practice, as a bridge between the NASA grades and the American Institute of Architects (AIA) Compensation Scale in Column 6. This description begins with the level of "apprentice" in recognition of the tradition that prevailed for centuries before professional degrees in architecture became the norm. In several states, including California, it is still provided under the law for a person to serve a seven-year apprenticeship in an architect's office, in lieu of professional degree in architecture to qualify for an internship. The entry level with a liberal arts degree in architecture is thus an equivalent of such an apprenticeship. The first level at which the employee can hold the position title of "Architect" comes only when he or she passes the architectural license exam and earns the legal title "Architect."

Column 5 shows the role of academic degrees in the architectural profession, with the liberal arts B.A. in architecture the equivalent of an apprentice or "Intern I," the B.Arch., a bachelor as a "first professional degree," as roughly the equivalent of a Junior Intern, and an M.Arch. as a first professional degree as the equivalent of a Senior Intern.

Column 6 shows the American Institute of Architects Compensation scale, which the AIA uses to take surveys of its members and their firms (Czarnecki, 2002, p. 32). It is not meant to suggest that all or most architecture firms use all the grades indicated. TABLE 3 is not intended to suggest any specific correlation in monetary compensation among the career ladders described.

THE TWO CONTROVERSIES

AeroSpace Architects are currently engaged in a lively debate on two issues concerning professional qualifications for design and research: the role of licensing and the role of the doctorate in the profession. Both these issues go to the essence of AeroSpace Architecture as a *discipline.* The issue to arise first was the role of professional licensing. The second issue to arise was the role of the doctorate in architectural design research. The fundamental question for both these controversies is whether AeroSpace Architecture constitutes an extension of a continuum of terrestrial practice – in architecture or research – or, whether it marks a radical new departure in both architecture and research. Each of these issues has the potential to divide the AeroSpace Architecture Community or to bring it together and make it stronger.

<u>Licensing</u>

Licensing is by far the more controversial of the two issues among the current practitioners. For terrestrial architects, the license is the standard established by all 50 states that the architect is qualified professionally to protect the health and safety of the public. In all 50 states it is a violation of the law for an unlicensed individual to hold out himself or herself as an architect.

<u>Implications of the View of History</u> The position one takes with regard to the licensing question turns to a significant degree upon how one regards the place of AeroSpace Architecture in the progression of architectural history. If one believes that Space Architecture stands at the leading edge of a continuum of architectural history, then it is natural to believe in the necessity of attaining terrestrial professional qualifications, that is, an architect's license. If one believes that AeroSpace Architecture is an entirely new departure, untied to architectural history, then one may be inclined to dismiss the need for professional qualifications as an Earth architect.

<u>Professional Recognition</u> The NASA Occupational Series explains why a similar qualification is essential for AeroSpace Architects as well. The architect is quite analogous to the medical doctor in this regard. Neither NASA nor any other federal agency would hire a self-proclaimed doctor, or even think of justifying it on the basis of "equivalent experience" or "time in grade." It is vital for architects to attain a professional status equal to M.D.s within the space community. Equally, it is important for AeroSpace Architects to attain recognition within the larger architectural profession. The only way that the architectural profession will endow the AeroSpace practitioners with such respect is if they are licensed.

<u>Academic Preparation</u> One of the problems with the few university programs in Space Architecture is that – when successful -- they may send graduates directly into space programs without serving an internship in a licensed architect's office. In this regard, these programs may tend to mislead graduates into thinking they should pursue a very focused career in Space Architecture without professional training or qualifications, including licensure. The result has been a number of architectural graduates who never developed professional skills who found jobs in the Space Program, and who think of themselves as architects, but in they lack the requisite skills acquired through actual practice. Also, they cannot offer their services to practice architecture legally in any state in the United States.

TABLE 3. Approximate Correlation of Levels of Responsibility:
NASA Civil Service Grades to Architectural Profession Levels

1 **NASA GS Civil Service Grade**	2 **NASA Degree** Requirements or Equivalents **“Equipment Development”**	3 **NASA Degree** Requirements or Equivalent **“Research”**	4 **Architecture Professional Practice** Generic Description	5 **Architecture Profession Degree** Requirements or Equivalent	6 **American Institute of Architects** Compensation Scale
GS-7	B.A., B.Arch., B.S.	B.A., B.S.	Apprentice	B.A.	Intern I
GS-9	M.A., M.Arch., M.S.	M.A., M.S.,	Junior Intern	B.Arch.,	Intern II,
GS-11			Senior Intern	M.Arch.	Intern III
GS-12		Ph.D.	Associate Architect	License	Architect I, Architect II
GS-13			Architect		Architect II, Architect III
GS-14			Senior Architect		Senior Architect/ Project Manager
GS-15			Managing Architect		Department Head/ Senior Manager

Quality Metric Licensing also provides a quality metric for professional practice in AeroSpace as well as on the Earth. But it also does more. It establishes the continuum from terrestrial to extraterrestrial architecture. If an architect does not know how to draw construction documents for a foundation that will secure a building permit on Earth, how will he or she design a foundation for Mars?

Two Paths to Resolution There are two paths to resolve this controversy. The first path is to plan and organize opportunities for architectural graduates within the agency to serve an internship under a licensed architect – either within NASA or through an arrangement with a private practice. The second path is to consider “grandfathering” these architectural graduates into a new AST-AeroSpace Architect specialty, and waive the licensing requirement this one time. Which approach would be the best path for each individual or for the architectural graduate community as a whole? This question should be the focus of further discussion during this Symposium.

The Doctorate

The role of a doctoral degree in Architecture or Architectural Research is rather more obscure than that of the license. At present most of the AeroSpace Architects with doctoral degrees teach in universities. At present, there is only one (the author) in NASA. The doctorate is analogous to the architectural license in the sense that not only is it the “union card” to teach at a university, it is a certification that the *doctor* is qualified to do research and ***to create new knowledge.*** The doctorate goes to a quality metric for design research.

The Doctor Knows Where the role of the doctorate attracts controversy is the idea that there are standards for design research and for the research publications. To simplify, a person who successfully passes through a rigorous doctoral program at a university knows how to perform research, how to do a literature review, how to develop a research design and to carry it out. The *doctor* knows the difference between research and the quick and dirty trade study. The *doctor* knows what valid reference citations are for research and how they differ from citing two or three untraceable internal reports – the currency of all too many projects. The *doctor* understands threats to validity and how to handle them. This list could extend much longer, but these examples should suffice to make the point.

Establishing Standards

The answer is that it is essential for AeroSpace Architects to establish standards for themselves both in design practice and in research. Only by establishing these standards and by living up to them will the AeroSpace Architect garner the respect and status they deserve within NASA and the aerospace community. Only by connecting themselves to the terrestrial/extraterrestrial continuum will AeroSpace Architects stand as an extension of their profession beyond the bonds of Earth.

CONCLUSION

This essay concludes with the proposal that NASA establish a specific occupational specialty, the AeroSpace Architect. A detailed description of this position and its career path appears in the APPENDIX.

AeroSpace Architecture constitutes the leading edge of a spectrum of several millennia of development in architecture. The fact that it is a continuum means that the rich body of architectural history and theory applies in important ways to AeroSpace Architecture. The argument cannot stand that AeroSpace Architecture -- particularly orbital or planetary architecture -- is a separate and revolutionary new departure. This continuum implies the importance of licensure.

Similarly, the argument that design research for Space Architecture is an entirely new field and so does not need to meet normal academic or scientific standards cannot stand. For research in AeroSpace Architecture to meet the critical tests of validity, generalizability and significance, it must be comparable to standard methods of research. While it is possible for individuals with varying degrees of expertise to contribute to the quest for knowledge in AeroSpace Architecture, the standard credential for "creating new knowledge" through research remains the doctorate.

The proposal for a new AST-AeroSpace Architecture specialty incorporates both these considerations in the development of the career ladder described in the APPENDIX.

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DEFINITIONS

AIA: American Institute of Architects

AIAA: American Institute of Aeronautics and Astronautics

ARC: NASA-Ames Research Center

Arch.D.: Doctor of Architecture degree.

AST: Aerospace Technology Series of NASA specialty positions.

B.A.: Bachelor of Arts degree

B.Arch.: Bachelor of Architecture Degree

B.S.: Bachelor of Science degree

M.A.: Master of Arts degree

M.Arch.: Master of Architecture degree

M.S.: Master of Science degree

GS: General Schedule of the US federal civil service.

JSC: NASA-Johnson Space Center

M.D.: Doctor of Medicine degree

NASA: National Aeronautics and Space Administration

OPM: Office of Personnel Management

Ph.D.: Doctor of Philosophy Degree

APPENDIX:

THE AEROSPACE ARCHITECT SPECIALTY

Position Description / Grade Evaluation Guide

725-18 AST-Aerospace Architecture Series,

GS-07 to GS-15

The AeroSpace Architect is an occupational series that encompasses design, planning, research and project management for living and working environments, architectures, configurations, and systems for aeronautical and space missions. The AeroSpace Architect brings a broad and holistic understanding of humans in the designed environment to these missions. The design products and subjects of research include such projects as earth-based facilities that uniquely support aeronautical and space missions; the design of airborne capabilities such as earth and atmospheric science and astronomy; orbital and planetary spacecraft and space stations; planetary bases, habitats and surface construction, interplanetary vehicles and missions.

The common nexus of these AeroSpace Architecture domains is the design for *extreme environments* such as Arctic/Antarctic, high altitude, orbital, planetary and underground habitats. The primary focus of the AeroSpace Architect is missions that involve human crews; however, it may also incorporate unmanned, automated, remote or tele-operated missions that directly or indirectly support future or concurrent human missions. The AeroSpace Architect spans a continuum from terrestrial to extraterrestrial design.

DESIGN RESEARCH

The AeroSpace Architect develops and performs research *in design* that enables the agency to develop new or better capabilities and understandings. AeroSpace Architects pursue research on both the theoretical and professional levels. On the theoretical level, design research includes investigation on the theoretical level of design conceptualization, methods, methodologies, perceptions, processes, protocols, representations and tools. On the professional level, design research includes investigation of design analysis, assumptions, delineation, documentation, integration, management, materials, modeling, operations, optimization, planning, product and projects, specification, structure, and technology. Often, AeroSpace architects must conduct investigations at both levels.

SAFETY

Safety is NASA's highest priority. The architect has a unique position for space missions and facilities because the definition of architectural licensure is a demonstrated ability to protect the health and safety of the public. Both the aeronautical and space environments are far more unforgiving of failure that can lead to a safety hazard than the terrestrial environment. Safety in aviation is governed by well-established regulation, but safety in space is very much a learning experience. The AeroSpace Architect applies the holistic understanding of humans in designed systems to enhancing crew safety on space missions.

PROFESSIONAL DESIGN

The AeroSpace Architect applies design research and focus on safety to the administration, creation, execution, integration, production, realization, and system assurance of aerospace capabilities and missions. The Architect brings highly developed and refined design skills and sensibilities to design process and to creating outstanding products and projects. The Architect differs from engineers in that engineers receive training with an ever-narrowing focus upon specialization. While the architect is always a specialist in design for living and working, the architect brings a meta-analytical specialty in design integration. This Design Integration involves the integration of the other design disciplines such as engineering, ergonomics, human factors, industrial design, information technology, interior design, mechanical and electrical systems, and structures into the physical architecture and mission architecture.

PROJECTS

AeroSpace Architecture projects often present a dual aspect of being research vehicles, but also serving an end in themselves as a completed artifact or product. These the design/research activities to achieve them may include drawing, CAD, 3D modeling and rendering, virtual environments, physical models and full scale mock-ups. Projects may include crew equipment, habitat and living and working environment outfitting, crew stations, simulators, and engineering prototypes. Larger projects may include complete space habitats, orbital and planetary bases and interplanetary vehicles. Programmatic design and design research encompasses Mission Architecture, System Analysis and System Integration.

INNOVATION

Innovation plays a very important role in the AeroSpace Architect series. Incumbents at all levels may contribute as appropriate to new design concepts, fabrication documents, inventions, patents and other original work.

PUBLICATIONS

Given the reality that a NASA employee may see only two or three major space programs over the course of a career, it is vitally important to capture corporate knowledge and document it for future projects and employees. As an AeroSpace Architect advances in grade level, it becomes increasingly important to document design projects and research to assure traceability, to create a permanent record and to communicate results and new knowledge to the space community on the agency, national and international scales.

EVALUATION STANDARDS

Evaluation for promotion shall be based upon the Equipment Development Evaluation Guide or the Research Evaluation Guide, whichever will present the incumbent's work in the most positive light. The application of the Equipment Development Guide shall consider conceptual design projects in addition to projects that proceed further through the production sequence outlined in TABLE 1. However, progress through the project phases is not intended correlate with advancement through the grades. The application of the Research Guide shall consider the incumbent's research in the context of other Design Research. To make this consideration, the evaluation must involve knowledge of comparable design research, or allow the incumbent to demonstrate the comparability.

Publications form an important part of the incumbent's responsibility, increasing in proportion with higher grades. Due to the present absence of refereed and peer-reviewed publications in the field of AeroSpace Architecture, the agency shall evaluate publications for quality, originality, expertise, creating new knowledge and significance to the agency and the national and international aerospace communities. If the incumbent publishes in a peer-reviewed or refereed journal in a different discipline, that may be weighed in favor, but the absence of such journal publications shall not be weighed against the incumbent.

POSITIONS — GRADES

The General Schedule Grade appears in Bold.
(A semi-formal title that correlates the grade to the profession of Architecture appears in Italics)

<u>GS-07 AeroSpace Architect</u>
(Apprentice Architect)

QUALIFICATIONS: Bachelor of Arts or Science in Architecture or Architecture and Planning from an accredited school of Architecture.

SUPERVISION: This is a pre-professional apprenticeship position, in which the incumbent works under the guidance of a licensed architect or engineer.

DUTIES: The incumbent supports design work and research as an *Apprentice Architect* taking a role in aspects or portions of a project.

GUIDELINES: The incumbent learns and applies existing guidelines such as building codes and NASA STD-3000.

ORIGINALITY: The incumbent is learning to work within established concepts.

STANDING: Role within the Branch

<u>GS-09 AeroSpace Architect</u>
(Junior Intern Architect)

QUALIFICATIONS: Professional Degree in Architecture (usually an M.Arch). May be a B.Arch. professional degree, plus one year of professional experience.

SUPERVISION: This is a professional junior internship position, in which the incumbent works under the guidance of a licensed architect or engineer, learning and taking on professional responsibilities. The incumbent receives assignments from the mentor.

DUTIES: The incumbent supports design work and research, taking responsibility as an *Intern Architect* for planning and conceptual design of projects, design development and adapting model specifications to the project. The incumbent may serve as a Contracting Officer's Technical Representative (COTR) for discrete design or construction projects.

GUIDELINES: The incumbent applies existing guidelines such as building codes and NASA STD-3000.

ORIGINALITY: The incumbent develops new concepts within a well established project or mission architecture.

STANDING: Role within the Branch, support of Division planning and projects.

<u>GS-11 AeroSpace Architect</u>
(Senior Intern Architect)

QUALIFICATIONS: Professional degree in Architecture, Professional experience to work as a senior intern.

SUPERVISION: This is a professional senior internship position during which the incumbent prepares for professional licensure while working under the mentorship of a licensed architect or engineer. The incumbent receives assignments at a project level from the mentor, and takes initiatives to develop solutions.

DUTIES: The incumbent takes responsibility as an *Intern Architect* for a project in the schematic or conceptual and design development phases, creates construction documents such as working drawings and specifications. The incumbent performs research into the requirements, subsystems and technologies of a project.

GUIDELINES: The incumbent interprets and applies existing guidelines.

ORIGINALITY: The work requires a degree of creativity and originality to produce a suitable design project.

STANDING: Role in Branch and Division Projects.

PUBLICATIONS: Publish research and concepts in project or Center reports.

<u>GS-12 AeroSpace Architect</u>
(Associate Architect)

QUALIFICATIONS: Professional Licensure in Architecture. It is not possible to substitute time in grade or “equivalent experience” for licensure. The license is the credential that certifies the architect is capable of protecting the health and safety of the public as a prerequisite to protecting the health and safety of a space crew. Responsible experience in design of terrestrial architecture and aerospace facilities is a benchmark of the GS-12.

SUPERVISION: The incumbent works independently within the research goals or project guidelines, in taking full professional responsibility for the design and realization of a project through all phases of completion.

DUTIES: The incumbent takes charge as an *Associate Architect* of an architectural project or the architectural portion of a larger project within a team. The incumbent conducts design research in concepts, methods, planning, structures, technology, and values. The incumbent takes full responsibility for construction documents.

GUIDELINES: Guidelines exist in some areas, but where they are inadequate, the incumbent researches new approaches.

ORIGINALITY: The work requires significant originality in developing research strategies and design concepts.

STANDING: The incumbent gives advice to Branch, Division, and Directorate management, and serves as a member of a project team.

PUBLICATIONS: The incumbent publishes research and technical papers at the Center and Agency level.

GS-13 AeroSpace Architect
(Architect)

QUALIFICATIONS: As an accomplished and licensed professional architect, the incumbent is qualified to undertake research of known design problems and the development of entirely new design solutions to those problems.

SUPERVISION: The incumbent works largely as an independent professional within a broad program of research and technology development.

DUTIES: The incumbent researches and develops new design and planning concepts, methods, and processes. The incumbent takes responsibility as a *Lead Architect* for the overall idea and objectives of design research and design projects. The incumbent submits new innovations to the invention disclosure process. The incumbent works as an important consultant or expert on a project team, and gives advice to management at a Center level.

At the GS-13 level, Professional Design and Design Research diverge into three paths: Design of Projects and Products, Design Research and Combined Design and Design Research.

A) Professional Design of Projects and Products: The incumbent serves as a Technical and Design lead on a major agency mission, program or system. The incumbent applies advanced research to design activities. The incumbent makes recommendations for key design and planning decisions.

B) Design Research: The incumbent pursues basic, applied and programmatic research in design problems, design methods, methodologies and processes. This research leads to better understandings and capabilities for NASA missions, projects and systems.

C) Combined Professional Design and Design Research: In this combined specialty, the incumbent develops design concepts as a hypothesis about the nature of the design problem, using methods of "inquiry by design" and other design research methods. The incumbent creates "Ideal Designs" that model highly innovative solutions based upon design research.

GUIDELINES: Guidelines are inadequate. The incumbent must conduct independent research to develop sufficient and appropriate guidelines and apply them with professional judgment.

ORIGINALITY: The work requires a high degree of creativity and originality.

PUBLICATIONS: At the GS-13 level, publications become an important concomitant of the work, including papers at agency and national conferences. The incumbent organizes agency and national conference sessions.

GS-14 AeroSpace Architect
(Senior Architect)

QUALIFICATIONS: At the GS-14 level, the qualifications diverge on three paths that reflect the three duty paths that emerged at the GS-13 level. Generally, at the GS-14 level, the incumbent attacks new or previously unidentified or unknown design problems with design research and develops new and innovative design solutions for those problems.

A) Professional Design of Projects and Products: Licensed architect and the design of complete airborne working environment or a space living and working environment such as a space habitat (e.g. TransHab), space station, planetary base or interplanetary vehicle.

B) Design Research: An architect's license and doctorate is required in Architecture, Engineering, Planning or Science. The incumbent has a demonstrated record of design research results that influence agency projects.

C) Combined Professional Design and Design Research: An architect's license is required and a doctorate in Architecture, Engineering, Planning or Science is strongly indicated.

SUPERVISION: The incumbent develops design research and projects within the very broad programmatic goals of the agency, and contributes to defining and shaping those goals.

DUTIES: The incumbent's work is recognized at the agency and national level, where it has an impact on programs, policies, and practices. As a *Principal Architect*, the incumbent shapes agency programs and policies by chairing or leading agency-wide working groups and by contributing as an author to agency Design Reference Missions and to agency Research and Technology Road Maps.

A) Professional Design of Projects and Products: The incumbent conceives, creates, and carries out new projects or portions of larger projects. The incumbent serves as a design or technical group lead or as leader of a "Sub-Integrated Project Team"

B) Design Research: The incumbent carries out research investigations of design problems, methods, methodologies, and processes that are vital to the current or future programs of the agency.

C) Combined Professional Design and Design Research: The incumbent develops complete "Ideal Design" solutions to research design problems through inquiry by design.

GUIDELINES: Guidelines are inadequate to non-existent. The incumbent must apply research, originality and professional judgment to supplementing inadequate guidelines and to creating new guidelines where none exist.

ORIGINALITY: At the GS-14 level, the incumbents work is largely original and highly creative in developing research in new problems and new solutions for those new problems.

STANDING: The incumbent gives advice as a consultant and makes recommendations to the Agency management, and enjoys national standing through research publications and design accomplishments.

PUBLICATIONS: The incumbent publishes in national and international conferences and journals. The incumbent organizes and chairs technical sessions at international conferences.

GS-15 AeroSpace Architect
(Managing Architect)

QUALIFICATIONS: At the GS-15 level, the incumbent develops new programs of research and design to accomplish agency and national policy goals. These new agency programs and projects are intended to define and advance new architectural, exploration, mission, operational, scientific, system, or technical goals.

A) Professional Design of Projects and Products: Licensed architect and the design of complete airborne working environment or a space living and working environment such as a space habitat (e.g. TransHab), space station, planetary base or interplanetary vehicle.

B) Design Research: An architect's license and doctorate is required in Architecture, Engineering, Planning or Science. The incumbent has a demonstrated record of design research results that influence agency projects.

C) Combined Professional Design and Design Research: An architect's license is required and a doctorate in Architecture, Engineering, Planning or Science is strongly indicated. The incumbent has developed design models or Ideal Design that shape an agency's design policy.

SUPERVISION: The incumbent receives minimal supervision as he or she leads vital agency research and design programs.

DUTIES: The incumbent plays a leading role in helping to establish agency programs, policies and practices. As a *Senior Principal Architect*, the incumbent leads agency-wide studies such as Design Reference Missions, and conducts research and leads design projects that are truly essential to the success of NASA missions (e.g., Mars Returned Sample Handling, In Situ Resource Utilization).

A) Professional Design of Projects and Products: The incumbent conceives, creates, and carries out new programs that consist of one or more design projects. The incumbent serves as a leader of an "Integrated Project Team" to create and carry out this program or its projects.

B) Design Research: The incumbent carries out research investigations of design problems, methods, methodologies, and processes that are vital to the current or future programs of the agency.

C) Combined Professional Design and Design Research: The incumbent develops complete "Ideal Design" solutions to research design problems through inquiry by design.

GUIDELINES: Guidelines are non-existent, at least to the degree that they may exist only in theory and have yet to be applied or attempted in practice (e.g., NASA Planetary Protection Alpha PPL-α).

ORIGINALITY: The work is almost entirely original as it breaks new ground in most respects.

STANDING: The incumbent serves as a technical expert of international standing. The incumbent makes recommendations both to the agency and to international decision-making bodies.

PUBLICATIONS: The incumbent publishes technical papers at international conferences and journals and serves as a keynote or plenary speaker at such events. The incumbent organizes and chairs international colloquia, conferences and symposia.