Research and Practice on Knowledge Solidification in Aerospace Design Enterprises: Post-Print

Authors: Xiang Jing, Wang Xuemei

Date: 2023-10-08T00:00:00+00:00

Abstract

[Purpose / Significance] How to codify the model design experience of veteran experts and engineers, achieve the transformation of knowledge from tacit to explicit, and effectively promote knowledge accumulation, transformation, and application is a major challenge currently facing the development of China's aerospace industry. [Method / Process] This paper proposes a "position-profession-process" three-dimensional knowledge codification system model, and conducts knowledge codification practices through compiling position standard catalogs, designer manuals, design templates, and expert interviews, making beneficial attempts and explorations of effective mechanisms for knowledge creation, externalization, sharing, application, and inheritance. [Result / Conclusion] It has been effectively applied in the product development processes of internal unit models and related design units of the academy, demonstrating good exemplary effects.

Full Text

Preamble

ChinaXiv Cooperative Journal [Best Practice]
Research and Practice on Knowledge Solidification in Aerospace Design Enterprises
Xiang Jing, Wang Xuemei
Beijing Institute of Aerospace Systems Engineering, Beijing 100076

Abstract

[Purpose/Significance] How to solidify the design experience of senior experts and engineering personnel, transform knowledge from tacit to explicit, and effectively promote knowledge accumulation, transformation, and application represents a major challenge facing China's aerospace development.

[**Method/Process**] This paper proposes a "Position-Profession-Process" three-dimensional knowledge solidification system model, and conducts knowledge solidification practices through the development of position standard directories, designer manuals, design templates, and expert interviews, representing a beneficial exploration of effective mechanisms for knowledge creation, manifestation, sharing, application, and inheritance. [**Result/Conclusion**] This approach has been effectively applied in product development processes within the institute and related design units of the academy, demonstrating good exemplary effects.

Keywords: knowledge solidification; standard directory; design template; research practice
Classification Number: G251
Citation Format: Xiang Jing, Wang Xuemei. Research and Practice on Knowledge Solidification in Aerospace Design Enterprises [J/OL]. Knowledge Management Forum, 2017, 2(1): 77-81 [citation date]. http://www.kmf.ac.cn/p/1/100/.

Knowledge constitutes intangible corporate assets and a critical element for enhancing enterprise innovation capability and core competitiveness. China's aerospace industry has accumulated 60 years of model development experience, amassing substantial achievements and experience in model development and systems engineering management through various carriers such as drawings, patents, standards, design reports, and papers. However, knowledge remains fragmented, cannot be effectively integrated and shared, and a significant amount of experiential knowledge resides solely in personnel's minds. Knowledge solidification offers an effective solution to these problems by systematically organizing and refining knowledge and experience, transforming tacit knowledge into explicit form, and effectively promoting knowledge accumulation, transformation, and application.

The Beijing Institute of Aerospace Systems Engineering (hereinafter referred to as "the Institute"), as China's overall design organization for launch vehicles, has been actively exploring research and practice in design knowledge and experience solidification. By closely integrating professional technical systems, model development processes, and position requirements, the Institute has gradually progressed from "knowledge organization" to "knowledge solidification" and "knowledge application." Figure 1 [Figure 1: see original paper] illustrates milestone events in the Institute's knowledge management development across various stages.

1 Three-Dimensional Knowledge Solidification System

To address challenges including simultaneous development of multiple new models, difficult technological breakthroughs, high-density launch missions, and numerous new employees, the Institute innovatively proposed a "Position-Profession-Process" three-dimensional knowledge solidification system model (see Figure 2 [Figure 2: see original paper]). Through the development of posi-

tion implementation standard directories, designer manuals, design templates, and expert interviews, the Institute has achieved knowledge solidification, improved design efficiency, ensured design quality, fostered a culture of knowledge management and experience sharing, and effectively explored methods for knowledge creation, manifestation, sharing, application, and inheritance.

1.1 Position Axis

The Institute established position implementation standard directories and implemented a closed-loop management process through four stages—"selection," "formulation," "application," and "control"—to ensure implementation of standard system content at the position level. Designer manuals were compiled to distill work content, design methods, precautions, and quality issues at different design stages. Range work logs were developed to solidify range work procedures and content, with continuous revisions and updates based on changes in range workflows. Research and practice on position knowledge organization standards were conducted to solidify position knowledge, guide rapid growth of position personnel (especially newcomers), and promote talent development.

1.2 Profession Axis

A professional standard system was established to clarify construction planning for the professional standard system framework. Professional knowledge resources were organized to construct a professional knowledge model encompassing ten categories including experience taboos, failure cases, and standard specifications. This solidified the formation of professional knowledge resource organization specifications, promoted solidification of professional technical experience, and advanced professional technical development.

1.3 Process Axis

Design templates serve as carriers to embed core achievements and technical secrets such as input-output relationships, interfaces, methods, and standards in overall design. Decades of development experience and lessons were distilled to form standardized samples of design documents, achieving manifestation and systematic sharing of tacit knowledge. Through information-based application process control, the Institute ensured application of design templates in model development. Work on design elements for professional design documents was carried out to guarantee design quality. A knowledge management-based technical status management system and process was established and applied during the model demonstration phase, exploring implementation pathways for knowledge reuse and innovation methods in model development.

2.1.1 Development and Application of Position Implementation Standard Directories

According to position responsibility regulations, combined with position work characteristics, requirements, standard formulation/revision, and current application status of standard implementation, the Institute conducted comprehensive and systematic organization of standards required for each position, determining standard implementation requirements at two levels: "mastery" and "reference." By 2014, position implementation standard directories covered 98 positions at the Institute, with 13 sub-volumes compiled for 13 design offices, encompassing 4,966 professional technical standards.

The development and revision of position implementation standard directories follow annual dynamic management. Through initial planning, each research office compiles/revises its position standard directory sub-volume and completes internal review. Expert review is then organized to form the "Position Implementation Standard Directory." To improve closed-loop management of position implementation standard directories, feedback forms were developed to enhance applicability and operability.

2.1.2 Development and Application of Designer Manuals

To effectively implement position standard directories within the designer workforce, the Institute developed designer manuals in a targeted manner for each specialty. To standardize compilation content and create unified templates, the Institute first conducted discussions and trial compilations of the "Designer Manual Compilation Guidelines" in typical specialties of some research and design offices to guide subsequent manual writing across all specialties.

Designer manuals primarily cover: preface, design work, design techniques required for overall model specialties, historical problems encountered in overall model specialties, current domestic and international technology development directions and recommended materials for this specialty to follow, commonly used standard directories and main content indexes for this specialty, compilation and revision memoranda, and appendices. The Institute has currently developed 96 designer manuals, which effectively guide position personnel in design work, clarify design context, and improve design quality.

2.1.3 Development and Application of Range Work Logs

Since 2008, the Institute initiated compilation of range work logs, organizing and summarizing range work processes and position work content, and distilling work items, content, position responsibilities, precautions, and work standards for each model and position. The Institute has currently formed 51 range work logs, which effectively guide newcomers in range work, standardize range operations, and improve range work quality.

2.1.4 Organization and Application of Position Knowledge Packages

In 2012, the Institute selected two positions—power supply and measurement/control design, and electrical system overall design—as pilots for knowledge resource organization. Using position outputs as references, the Institute organized knowledge packages including design content and design elements, and applied them on the China Academy of Launch Vehicle Technology (hereinafter referred to as "the Academy") knowledge management platform, conducting practical exploration to expand ideas for knowledge resource organization.

In 2013, the Institute led the organization of position knowledge resources for a certain model development process. Combining model development processes, the Institute clarified position definition and classification, knowledge resource organization content, knowledge resource organization methods, and knowledge resource collection workflows, solidifying the formation of the "Position Knowledge Resource Organization Standard Based on Model Development Process." This provided guidance for knowledge resource organization in design, testing, and process positions during model development across the Academy.

2.2 Professional Dimension Knowledge Solidification

2.2.1 Building Professional Standard Systems

Following principles of unified professional standard system format, reasonable standard classification, and selection of applicable professional system standards, the Institute has established professional standard systems represented by digital engineering application standard systems and environmental test standard systems, and promoted their application across all design offices through pilot implementation.

Taking the digital engineering application standard system as an example, in developing the digital engineering application standard system table, the Institute divided model digital design work into four major aspects: digital foundation, digital design, digital simulation, and digital management. Sub-series were determined including digital collaborative design, 3D structural modeling, electrical system CHS drawing standards, flight simulation, attack-defense simulation, and electromagnetic compatibility simulation. Six standards including 3D design and assembly simulation were formulated, along with nine standards represented by the "Pro/E 3D Annotation General Specification." Concurrently, construction of design unit and system simulation-related standards was initiated. In 2009, after application, eight digital top-level standards were elevated to Academy standards. In 2012, after several years of accumulation, the Institute formed 224 standards related to model digital design, covering over 20 overall and subsystem specialties involved in model digital design work.

2.2.2 Organization and Application of Professional Knowledge Resources

In 2011, the Institute took the lead in the Academy to conduct professional knowledge management pilots. Starting from the professional technical system, the Institute constructed a professional knowledge management meta-model encompassing ten major categories of knowledge resource types: basic content, experience taboos, failure cases, shared models, latest developments, best practices, academic papers, invention patents, scientific and technological achievements, and standard specifications. The "Professional Dimension Classification Knowledge Management Measures (Trial)" was summarized and refined to guide knowledge resource organization across the Academy.

Currently, the Institute has completed the organization of nearly 1,000 knowledge resources across 16 specialties, 2 positions, and 2 models, which have been shared and applied on the Academy's knowledge management platform.

2.3.1 Development and Application of Design Templates

Design templates standardize interface relationships between documents and address significant differences in application methods of design documents between different models and variations in the same model's design documents at different development stages. Establishing an effective set of design templates serves both as a means of standard implementation and as a vehicle for accumulating and inheriting product design processes and experiential knowledge.

To standardize design template compilation, the Institute developed the "Design Template Compilation Guidelines," which specify responsibilities, compilation principles, requirements, and approval requirements for design template compilation, forming a design template compilation and review process.

Since 2008, the Institute has explored the establishment of a design template system. In 2009, with research and design offices as pilots, 17 design templates were released, forming the first batch. Between 2011 and 2014, four batches totaling over 140 design templates were developed. More than 200 existing design templates from current models were summarized and integrated, determining that 217 design documents required template development and forming a design template system framework.

To achieve information-based application of design templates, in 2014, over 200 templates were integrated into the AVIDM system, achieving 100% adoption of relevant design templates for design document compilation. Various optional formats for design document compilation are directly pushed to designers' desktops, guiding them to compile model design documents according to predetermined steps and requirements, thereby improving design quality and efficiency.

2.3.2 Development and Application of Design Elements

Since 2010, the Institute has conducted design element compilation work for major professional design documents. Design elements identify key and difficult points in major professional design documents, clarifying and explaining areas prone to errors or ambiguity, and serve as the basis for designers to check design document correctness. Taking the design elements for control system circuit comprehensive design task books as an example, 28 design elements were organized, specifying design factors and external inputs, design methods or formulas used for 28 critical contents including instrument power-on time, reliability requirements, key timing design during flight, and interfaces with various electrical systems.

2.3.3 Technical Status Management and Application

With rapid changes in model development situations, status changes during model feasibility demonstration phases, system scheme demonstration processes, and product design processes have become increasingly frequent, with design and implementation methods becoming increasingly diverse. To improve technical status management efficiency, the Institute established a scientific and standardized hierarchical management system that three-dimensionalizes large amounts of technical status knowledge concentrated at a single level, forming a pyramid-shaped hierarchical technical status knowledge and corresponding management process. On this basis, to support effective acquisition and application of massive knowledge information, the project team proposed a rapid intelligent push strategy for technical status knowledge. First, a strategy was proposed to classify retrieval personnel by role, concentrating knowledge searches on a single level of the hierarchical knowledge base. Second, on any level of the pyramid, a characteristic field database and dynamic knowledge map were established to achieve rapid matching, extension, and association in knowledge retrieval.

Currently, this method has been successfully applied to technical status management during the pre-development phase demonstration process of a certain model, verifying the scientific nature and efficiency of this system for technical status management and providing strong support for knowledge reuse and innovation in subsequent demonstration and development processes.

2.4 Other Knowledge Solidification Applications

To deeply mine the explicit and tacit knowledge resources of senior experts, in 2012, the Institute made solidifying expert experiential knowledge an important measure of knowledge engineering. The Institute organized a series of interviews with senior Academy experts such as Academicians Long Lehao and Liu Zhusheng, as well as department-level experts. Through the compilation of "Knowledge Management Briefings," the Institute organized experts' growth experiences, technical breakthroughs, scientific research management, and ideas

on future domain development, better solidifying and sharing expert experiential knowledge and achieving knowledge inheritance.

Professional and management knowledge was promptly summarized, refined, and shared through knowledge tips, forming a unified knowledge tip template to standardize knowledge tip publication. Currently, the Institute has over 10,000 professional technical tips.

In 2013, the Institute took structural design as a pilot to conduct research and application of structural multidisciplinary design knowledge communities. A launch vehicle structure knowledge management platform was constructed to achieve organized management and knowledge push at each design stage. A professional knowledge community was established to facilitate professional exchange and knowledge sharing, with the knowledge community model being promoted and applied across the Academy.

3 Practical Application Effects

Through exploration and efforts in knowledge solidification in recent years, position standard directories, designer manuals, design templates, and expert interviews have been effectively applied in the Institute's internal models and related design units' product development processes within the Academy, demonstrating good exemplary effects.

Through knowledge solidification applications, particularly position knowledge solidification and application, the quality of model products has been effectively improved and personnel training accelerated. The cycle for new employees to independently complete design documents has been shortened by 50% compared to before. For example, the time for new employees to produce a complete load calculation and analysis document was reduced from one month to half a month. The error rate in model design documents has been reduced by over 80%. For instance, design documents compiled according to design templates are returned during approval processes no more than three times, compared to more than ten times previously.

The Institute's knowledge solidification methods have been successfully applied to model product design and have been promoted and applied both within and outside the Academy. During the development of a certain model from 2010 to 2013, the comprehensive implementation of design templates played a significant role in risk control throughout overall design, large-scale testing, and flight testing, ensuring smooth project development. The issued design templates have been widely applied in the design processes of various models across the Academy, effectively standardizing design, improving design document quality, and enhancing design capabilities.

Furthermore, the Institute-led development of regulations such as the "Academy Professional Dimension Classification Knowledge Management Measures (Trial)" and "Position Knowledge Resource Organization Standard

Based on Model Development Process" has effectively guided knowledge resource organization and application across the Academy, promoting knowledge inheritance and technical infrastructure development.

References

[1] Zhang Xuhui, Zhang Bing, Rong Yi, et al. Exploration and Application of Model Design Knowledge Management [J]. Aerospace Industry Management, 2012(7): 10-14.
[2] Xiang Jing, Wang Yinghao, Liu Jingdong, et al. Research and Practice of Knowledge Management Based on Professional Technical System [J]. Aerospace Industry Management, 2013(5): 34-36.
[3] Xie Xuan, Zhu Xuechang. Compiling Design Templates to Improve Design Quality [J]. Aerospace Standardization, 2011(2): 44.
[4] Zhao Bo, Pi Zan, Xie Xuan. Research and Practice of Aerospace Product Digital Standard System [J]. Aerospace Standardization, 2013(2): 1-5.

Author Contributions:
Xiang Jing: Responsible for constructing and practicing the professional and position-based knowledge solidification system.
Wang Xuemei: Responsible for constructing and practicing the process-based knowledge solidification system.

Note: Figure translations are in progress. See original paper for figures.