SimuValid™ : Innovation through New Integration in Space Equipment Thermal Validation

Tatsuya Murakami Yuuta Nishida Masahiro Kudo
Takaharu Nakamura Sakura Morimoto

In recent years, new entrants have been gaining momentum in the space industry and related markets. When using terrestrial products in a space environment, it is necessary to ensure safety and reliability in harsh conditions such as vacuum and rapid temperature changes. However, achieving such high design quality can be limited by traditional methods that rely on trial-and-error using actual equipment and ground-level perspective.

OKI-EMS Division (OKI-EMS) has systematically integrated the technologies, design knowledges, and core components possessed by its group companies using the concept of new combination (innovation) to create a new service called SimuValid™*1). SimuValid is a portmanteau derived by combining the words "simulation" and "validation." It is a new service that provides one-stop support from the design stage to actual equipment validation. This article describes SimuValid's unique process and the key points that have contributed to value creation at monozukuri (manufacturing) sites.

Value Created by New Combination of Technologies

The biggest feature of SimuValid is the organic collaboration between OKI-EMS Group companies, each with their own monozukuri expertise, to solve thermal issues. In the development of space equipment, thermal design is crucial to ensure safety and reliability under harsh environmental conditions. Heat is a fundamental issue that directly leads to failures and performance degradation in space equipment, and high-quality design is essential for any solution.

SimuValid covers the major technical areas of thermal analysis simulation (desktop study), validation (physical evaluation), heat dissipation technology (countermeasure technology), and cause analysis (failure analysis) with the expertise of three companies: OKI IDS (OIDS), OKI Circuit Technology (OTC), and OKI Engineering (OEG). By integrating the three companies' technologies and knowledge through new combination (innovation), it was possible to achieve essential solutions to thermal issues and improve design quality, both of which would not have been possible for any individual company to achieve on its own.

In actual development, OIDS utilized thermal simulations from the initial stage to identify risk factors and optimal solutions for heat dissipation design, and based on those design proposals, layout of the boards and components was considered. Additionally, in areas that are particularly thermally demanding or where higher reliability and safety margins are required, OTC proposed high-value-added heat dissipation technologies such as copper coin embedded printed circuit boards (PCBs). Copper coin embedded PCBs are a solution backed by OTC's unique advanced technology and extensive experience in the space field, and these PCBs demonstrate their true value in areas that cannot be addressed with conventional heat dissipation designs or when further reliability enhancements are desired. OEG's actual equipment evaluation and failure analysis are effectively linked, and repeated feedback between desktop study and physical evaluation improves design quality and reliability. This new combination of technologies that supports SimuValid provides new value to clients' sites by addressing the root causes of thermal issues.

Design Quality Improvement and Model-Based Development

"How to improve design quality" is an issue that is becoming increasingly apparent in design and development sites across a wide range of fields, including space equipment development. While convection cooling, which utilizes airflow, is the norm for terrestrial applications, air cooling cannot be used in space, necessitating a fundamental rethinking of thermal design and component placement.

SimuValid first uses simulation and validation to reconcile design hypotheses with physical evaluations, enhancing the reliability of the model. Subsequently, simulation-driven design studies are repeated to accurately identify points requiring additional validation.

*1) SimuValid is a trademark of Oki Electric Industry Co., Ltd. in Japan.

This process is perfectly aligned with the concept of Model-Based Development (MBD), enabling early identification of potential risks and accelerated optimal design, and as a result, shortens development time and reduces cost.

SimuValid objectively ensures design quality and enables logical design decision-making without relying on traditional empirical rule or on individual physical evaluations. It also contributes to consensus building with clients and the accumulation of knowledge for next-generation designs. This will not only be a significant contribution to future space equipment development but also to improving design quality in a wide range of fields.

One-Stop Service for Realizing Essential Problem Solving

In monozukuri, dealing with defects and unexpected events can often be a “down and dirty” process. Through collaboration between the different technical fields of OIDS, OTC, and OEG, SimuValid provides a service that seamlessly handles everything from design/simulation to validation and failure analysis as well.

This three-pronged collaborative process covers a wide range of issues from the component level to the entire system. It quickly and reliably identifies the root causes of defects and issues that arise in the field and perform essential problem solving that will prevent reoccurrence.

SimuValid is true one-stop service since it eliminates runarounds and dispersion of responsibility. Group companies with the optimal technologies work closely together at every stage of development, from design to evaluation to analysis, enabling SimuValid to solve issues beginning at the site and continuing toward completion on a scale and depth that would be impossible for a one Group company to achieve alone.

With the highly reliable monozukuri capabilities unique to OKI-EMS at its core, SimuValid will continue to deepen its true one-stop service from design to manufacturing and quality assurance, which is difficult for other companies to achieve.

SimuValid Service’s Product Development Flow

To clarify the features of SimuValid, **Figure 1** shows the one-stop flow from design and development to manufacturing.

(1) Design Requirement Discussion and Simulation Utilization

Client’s requirements and development specifications are defined, and optimal design is proposed through simulation. Validation is also performed at the unit, module, and board levels.

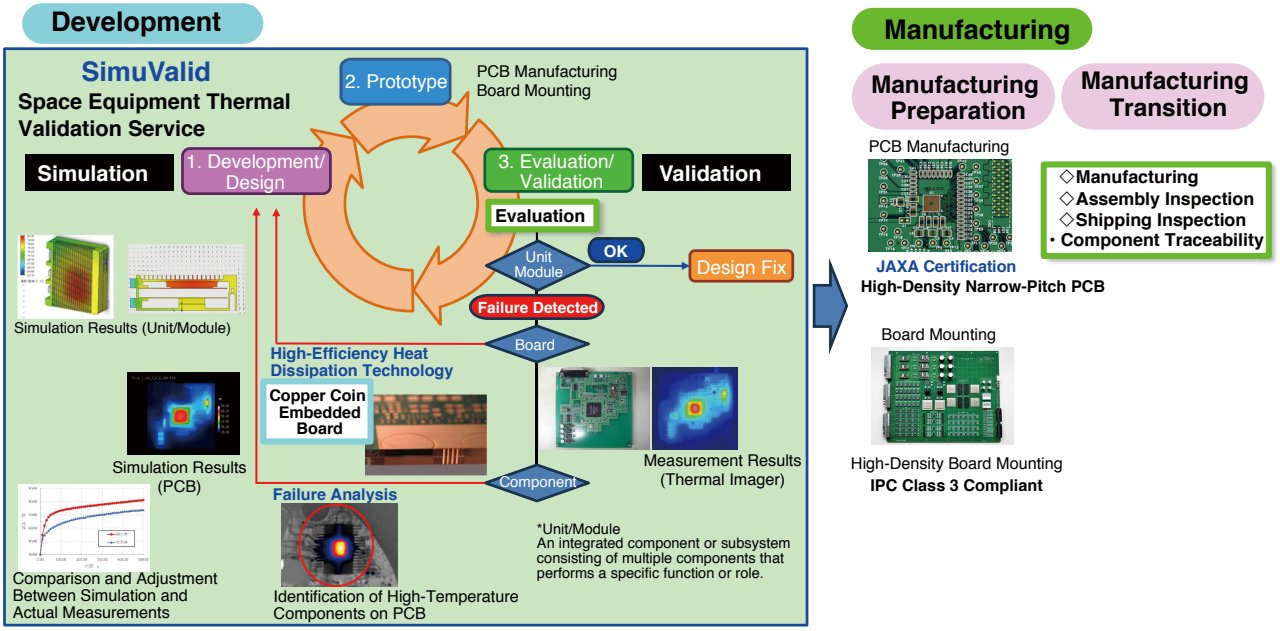

Figure 1. SimuValid Product Development Flow
Entire OKI-EMS Group works together to support client’s problem solving from design to manufacturing

(2) Design Optimization and Heat Dissipation Proposal When Targets Are Not Met

Layout optimization and OTC's heat dissipation technology are combined to develop and implement various countermeasures to meet specifications.

(3) Response to Failures and Unexpected Events

OEG's failure analysis identifies the root causes of failures and the problems are addressed by providing feedback to the design and assembly processes.

(4) Problem Resolution and Manufacturing Support

After the optimal design is finalized, OKI-EMS oversees the entire group, and OKI JIP (OJIP) provides end-to-end monozukuri support, from board mounting and assembly to inspection and traceability[1), 2)].

Individual Company's Technologies and Comprehensive Value Created by SimuValid

The value SimuValid delivers lies in the advanced specialized technologies that each OKI-EMS Group company has cultivated over the years and the cross-sectional collaboration between the companies. The following section introduces the core technology / knowledge of each company and explains how they integrate to deliver SimuValid's comprehensive strengths for monozukuri innovation.

- **OIDS Simulation Technology**

OIDS possesses simulation and analysis technology capable of conducting thermal reliability testing and thermal design for space equipment. Unlike terrestrial systems, space equipment, such as rockets and satellites, operates in a vacuum, creating a unique thermal environment where heat transfer primarily occurs through conduction and radiation. OIDS' strength lies in its proprietary thermal conduction simulation that is suited to this environment, and it has developed models that accurately incorporate numerical models of heat transfer paths, the materials of each layer of a PCB, through-hole density, board thickness, and the anisotropic thermal conductivity of materials.

To reproduce heat flow in a space equipment, OIDS employs a heat mass model. Heat mass model accurately reproduces the transfer of heat generated inside an equipment to external structures, such as the equipment body and enclosure, down to the mass, physical properties, and contact conditions. It allows for highly accurate prediction of localized heating, heat concentration, heat transfer at fixed parts, and temperature distribution in the space environment.

Furthermore, on space-use electronic equipment for which air cooling is difficult, transient thermal analysis is applied to simulate rapid temperature fluctuations, such as those occurring during launch and initial operation. This method is also effective for "give it a try" type development, identifying issues in the early design stage, improving design accuracy, and shortening development time. The design and evaluation knowledge accumulated by OIDS serves as a foundation for highly accurate space simulations[3)].

- **OTC Heat Dissipation Technology and PCB Development**

OTC is one of Japan's top manufacturers of PCBs for space equipment, and copper coin embedding technology is one of OTC's core technologies aimed at improving PCB heat dissipation. Incorporation of copper coins into PCBs enables structural designs that efficiently dissipate heat from electronic components to the enclosure. This technology can flexibly accommodate high-heat-resistant materials, multilayer composite boards, stress distribution, insulation, and high durability requirements. It also achieves both safety and durability by leveraging expertise in cross-sectional shape, fixation method, resin filling, and thermal cycle evaluation.

Copper coin embedded PCB can be proposed at the early stage of design, but rather than taking excessive measures when standard design is sufficient, it is flexibly adopted as a value-added technology when margins need to be secured or high reliability is required. OTC has a strong track record in the space market, having delivered approximately 90% of the PCBs for the H3 rocket and received certification from the Japan Aerospace Exploration Agency (JAXA). OTC provides one-stop support from design to manufacturing/validation with thorough management and traceability, and its strength lies in proposing a solution that is optimal for each application and requirement[4)].

- **OEG Validation and Failure Analysis Technology**

OEG possesses a reliability evaluation and failure analysis technology that covers a wide range from components to finished products. Reliability is a top priority for space equipment, and fully identifying the root cause of defects requires diligent analysis backed by experience and advanced analytical equipment. OEG utilizes various technologies, ranging from non-destructive testing, such as visual inspection, X-ray/ultrasonic detection, and heat generation analysis, to physical/scientific approaches, such as electrical property evaluation, cross-sectional structural

analysis, and elemental analysis, in order to quickly and accurately address the diverse failure mechanisms that arise during the assembly process.

The equipment supporting these analyses, a database of analysis cases, and a proven knowledge archive are also strengths that enable SimuValid to solve an on-site problem. OEG's presence prevents recurrence and leads to a fundamental solution, rather than simple Band-Aid solution. This allows SimuValid to provide a flexible service that can respond to a wide range of client needs, from the design stage to manufacturing quality control[5].

- **OKI-EMS and OJIP's Monozukuri Structure and High-Reliability Manufacturing Technology**

OKI-EMS and OJIP have organizational capabilities for implementing/manufacturing in high-reliability fields such as space equipment. They possess a structure that can support the entire monozukuri process, from design/simulation to prototyping/startup, manufacturing, and quality/traceability management.

They are also able to quickly respond to computerization / high-reliability designs in the automotive industry, handling micro-components such as 0402/0603, high-density mounting, and bottom termination components. They comply with global quality standards, such as IPC-A-610E Class 3, and possess technologies for X-ray internal solder defect inspection and high-heat-resistant/high-impact coatings.

The companies have a proven track record with the H3 rocket and other JAXA-related projects, and have used their organizational capabilities to address client issues from design to manufacturing. With OKI-EMS and OJIP, SimuValid is able to provide one-stop support that seamlessly handles everything from design to manufacturing / quality assurance[6].

Service Targets and Use Cases

SimuValid appeals to a wide range of clients, from those revising their design processes and improving cost efficiency in order to adapt their terrestrial products to space applications to those in the early stages of entering the space industry.

For example, when redesigning a terrestrial unit or module with fan cooling for space applications, SimuValid serves as a comprehensive monozukuri solution that provides support from thermal design to heat dissipation material selection/application, actual machine validation, and manufacturing. Particularly, in new markets that face harsh thermal environments or requires high reliability, SimuValid can provide quality assurance and improved process efficiency through scientific risk assessment and optimal design considerations from the initial design stage.

SimuValid aims to continue serving as a reliable development/manufacturing platform, working with clients to take on new monozukuri challenges in the space business and high-reliability fields.

Problem Solving Through New Integration Innovation

SimuValid integrates the simulation, thermal design, evaluation/analysis, and manufacturing technologies of OIDS, OTC, OEG, and OKI-EMS under the concept of new combination (innovation). Close collaboration between each company's technologies in the operation field and in design/development enables rapid resolution of design qualities and difficult issues that would not have been possible with one company working alone. This technological integration creates new value that transcends fields and functions and can be considered an example of innovation in practice

SimuValid will initially launch as "SimuValid Thermal™*2) (tentative)," a platform specializing in thermal issues. Plans are underway to expand into new areas such as weight reduction, vibration resistance, and shock resistance with "SimuValid Structure™*3) (tentative)." This evolution and value creation is supported by the end-to-end monozukuri service that encompasses everything from design to implementation, manufacturing, and quality assurance made possible through the collective strength of group companies, including OKI-EMS.

Going forward, the OKI-EMS Group will continue to combine its core technologies and knowledge to promote the evolution of its platform to provide a flexible, one-stop support to clients' diverse development themes, and continue to take on the challenge of creating new value.

◆◆

References

1) OKI Press Release, "SimuValid," a space equipment thermal validation service that provides comprehensive thermal analysis simulation, actual equipment validation, and failure analysis for rocket and satellite-mounted equipment is launched, January 28, 2025
https://www.oki.com/jp/press/2025/01/z24061.html (in Japanese)

*2) SimuValid Thermal is a trademark of Oki Electric Industry Co., Ltd. in Japan.
*3) SimuValid Structure is a trademark of Oki Electric Industry Co., Ltd. in Japan.

2) Space Equipment Thermal Validation Service “SimuValid,” OKI IDS Co., Ltd.
https://www.oki-oids.jp/solution/products/SimuValid.html (in Japanese)
3) Naoya Tonooka, Keiichi Fujino: Thermal Analysis of Rocket-Mounted Enclosures - Simulation of Unsteady Heat Transfer in Vacuum Environment -, OKI Technical Review, Issue 243, Vol.91, No.1, December 2024
4) Akihiro Yamamura: Manufacturing Method of Printed Wiring Board with High Heat Dissipation, OKI Technical Review, Issue 243, Vol.91, No.1, December 2024
5) Thermal Transient Characteristics Analysis, Oki Engineering Co., Ltd.
https://www.oeg.co.jp/analysis/thermal.html (in Japanese)
6) EMS (Design/Manufacturing Outsource Service), Electronics Manufacturing Services Division, Oki Electric Industry Co., Ltd.
https://www.oki.com/jp/Advanced-ems/works/space.html (in Japanese)

Authors

Tatsuya Murakami, Business Promotion SE Department, Business Management Division, OKI IDS Co., Ltd.

Yuuta Nishida, Business Planning and Management Department, Electronics Manufacturing Services Division, Oki Electric Industry Co., Ltd.

Masahiro Kudo, Business Planning Department, Business Promotion Division, OKI Circuit Technology Co., Ltd.

Takaharu Nakamura, Business Planning & Management Division, Oki Engineering Co., Ltd.

Sakura Morimoto, EMS Business Promotion Department, Industry Business Promotion Division, Oki Electric Industry Co., Ltd.

TIPS【Glossary】

SimuValid
SimuValid is a portmanteau derived by combining the words “simulation” and “validation.” It is an OKI-EMS Group service that provides one-stop support from design to analysis/validation.

New Combination
Combining technologies and knowledge from different fields/functions to create innovative results and new value that cannot be achieved alone. It is one of Schumpeter's definitions of innovation.

Transient Thermal Analysis
A method for analyzing temperature distribution that changes over time. It is used in space equipment and environments with rapidly fluctuating temperatures.

Copper Coin
A heat transfer component embedded within a circuit board that efficiently transfers heat from components between the front and back of the board. Space equipment and high-heat-dissipation printed circuit boards are typical examples.

JAXA Certification
Quality and safety certification by the Japan Aerospace Exploration Agency. Applied to circuit boards, components, and equipment approved for space-use.

0402/0603 Components
0402 and 0603 are surface-mount chip component standards. 0402 measures 0.4mm long x 0.2mm wide, and 0603 measures 0.6mm long x 0.3mm wide. They are used for miniaturizing electronic devices and for high-density mounting.

IPC-A-610E Class 3
This is an international quality standard for PCB assembly established by the Institute for Printed Circuits. Class 3 represents the highest standard of acceptance for “High Performance/Harsh Environment Electronic Products,” where high reliability and safety are required such as for aerospace and medical devices.