

Integrated Systems Commissioning

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Abstract:

To meet increasing performance requirements and environmental and energy standards building systems have become more complex and interdependent, and increasingly integrated with the building's physics and the occupant's behaviour. To deliver the required outcomes buildings and their systems must now be commissioned with a more sophisticated approach than that generally applied in the past and designers must play a far more active role in the commissioning of their designs. This paper provides an approach to integrated systems commissioning and offers insights into how the role of commissioning must grow and develop in the future.

1. BACKGROUND

Traditionally the commissioning of building systems has fulfilled three roles:

- Set up and test systems to ensure they will operate reliably and as the designer intended to provide the specified internal comfort conditions.
- Record system settings and operating attributes (airflow's, water flows, temperatures etc) to verify system performance and provide documentation for future reference, and
- Provide handover briefing and or training for building system maintainers and operators.

Unfortunately the commissioning process on many commercial construction projects is dysfunctional. In many ways the design and building services delivery process today is much less integrated than it was ten to fifteen years ago. There are a range of factors that have contributed to the current situation. These include:

- Reduced input from the original system designers in the construction and commissioning stages on many projects. This can result in unclear or no commissioning objectives, inadequate acceptance criteria, leading to no more than functional testing, and the transference to the building owner and operator of only perfunctory commissioning data and generic operating and maintenance manuals
- Increasing trend towards design and construct delivery models with a focus on construction outcomes rather than the design outcomes or life cycle outcomes.
- Increasing sophistication and complexity of building systems technology and the consequent specialisation and isolation of installation trades resulting in non integrated systems and technology applications that do not fully deliver the promised benefits.
- Lack of clear and readily defined and measured performance standards for buildings.
- Overwhelming commercial pressures to complete the project for least cost and on time to meet the contractual Practical Completion date and avoid onerous delay penalties.

Against this less than satisfactory background we now have a number of strong drivers to improve the effectiveness of buildings and building services - We have an increasing consciousness of the effect that buildings have on the environment and the need to minimise this for the long term. Also there is now a very significant concentration of building ownership in the hands of institutional type investors with a long term focus on the performance of the asset. This is translating to a new appreciation of life cycle issues and an improved understanding of the connection between well performing building services and tenant satisfaction and retention.

These drivers and the advent of energy and environmental building rating systems such as the Australian Building Greenhouse Rating System (ABGRS) and the Green Building Council of Australia "Greenstar" suite of environmental rating tools are providing the market with the impetus and the tools needed to demand, and importantly measure, better outcomes from their buildings, challenging the design and construction process to deliver a much improved product.

To produce the required performance outcomes buildings and their systems must now be commissioned with a more sophisticated approach than that generally applied in the past. A good integration of the design, construction and commissioning process is essential to delivering a high performance, operationally energy efficient and environmentally conscious building.

2. INTEGRATED SYSTEMS COMMISSIONING

Integrated commissioning models are required at three levels:

- The Project Knowledge Value Chain
- Integration of Active Building Services, Passive Design Features and Occupant Behaviour, and
- The Commissioning Body of Knowledge

2.1 Project Knowledge Value Chain

Development and Retention of Building Knowledge

The key principle behind the Project Knowledge Value Chain is that the knowledge base in relation to the design, installation, performance and operation of a building should be continuously developed, captured and managed. The focus is therefore on transfer of knowledge from one stage of a building's life cycle to the next with an aim to convert information and learning into retained knowledge. This concept is depicted in Figure 1.

Figure 1. Project Knowledge Base Development

To determine the key requirements of the model it is necessary to consider the information or knowledge generated at each stage of the project and what needs to be retained for future reference by the various stake-holders in the project, and the buildings life cycle. It is also worth considering what documentation is typically available as the project progresses.

Design Phase.

The design process is principally concerned with developing and defining the brief, the concept design and schematic designs. This is the critical high value component of the *engineering* service. Design development further refines the design and provides the documentation to allow the project to be progressed.

From a services design perspective, the critical aspect of the design process is the schematic design and the control strategies. Without a clear view of how the systems are intended to work and how they can be commissioned it is foolhardy to proceed to design development.

Whilst generic quality specifications (e.g. Natspec) provide clarity in terms of standards and quality assurance processes, specification writers need to ensure that the project specific requirements are fully documented.

Design Documentation is not necessarily the same as documentation suitable for obtaining competitive tenders, as the name suggests, tender documentation should document the design to actually add value and should include:

- A project description providing an overview of the project and the design objectives including factors such as energy or environmental rating requirements.
- A description of the services including any special requirements or design features, etc.
- Design Criteria
- Schematic Drawings which includes key design information, control strategies and equipment sizing.
- Control Strategies.
- Commissioning requirements and acceptance criteria

This information should be captured and provides a solid basis for the commissioning process to begin. Illustrative examples of a typical design schematic and an enhanced version including high value “project knowledge” are shown in Figures 2 & 3 below.

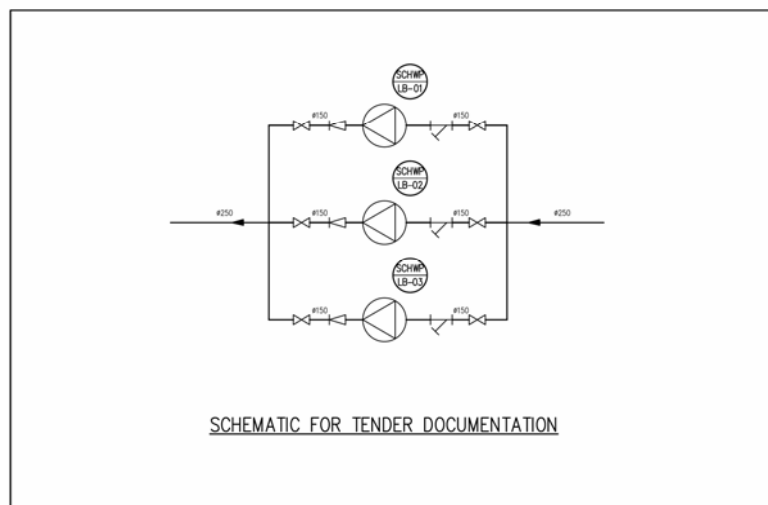


Figure 2. Typical Schematic for Tender

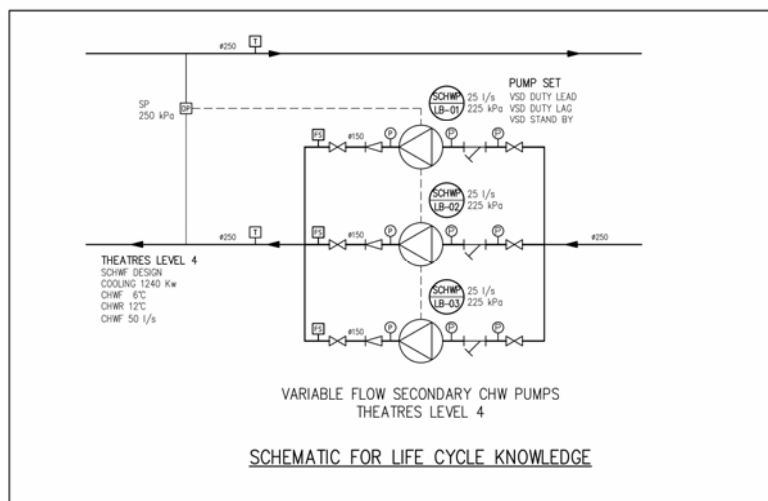


Figure 3. Schematic for Project Knowledge Value Chain

Construction, Commissioning, Handover and Building Tuning:

The commissioning process should be fully integrated with the tendering, construction and handover process to be effective. Whilst some installers outsource commissioning, commissioning input at an early stage can avoid costly mistakes later on in the project.

Commissioning activities in the tendering, construction and handover process should include:

- An initial review of the design and proposed equipment selections to ascertain any potential issues
- Review of the control strategies and system schematics
- Review of the shop drawings to ensure that the installation can be adequately maintained.
- Preparation of the Commissioning Management Plan outlining the sequence of activities, key dependencies and Inspection Test Plans.
- Preparation of Inspection Test Plans which are fully integrated into the design process by tracing their acceptance criteria back to the specification or relevant performance standard.
- Completion of the pre hand over commissioning activities and preparation of the records.
- Completion of seasonal building tuning activities during defects liability / warranty period and preparation of tuning records and guidelines.
- Input to energy and water efficiency improvements to achieve building performance (star rating) targets.
- Progressive operator / maintainer training
- Input to Operating and Maintenance Manuals

At the completion of the commissioning process, usually at handover, although preferably at the end of the warranty period, the future of the system knowledge hangs in the balance. It is at this point that the major dislocation in the knowledge chain typically occurs with often only limited design, installation and commissioning knowledge captured and effectively passed onto subsequent stakeholders in the building. It is important that protocols and procedures be put in place to archive the relevant knowledge in an appropriate format and to assure that is passed on to the relevant parties.

It is also worth noting that the production of relevant and particular commissioning records is required for specific credits towards accreditation of the buildings actual performance under the Greenstar Rating Systems.

For regulatory compliance the commissioning and testing of fire and life safety essential services is required for certification. Annual testing to prove that the systems still operate in accordance with their design intent and the performance levels recorded at Practical Completion is required for ongoing certification. The integrated knowledge model therefore should provide the following documentation in the Maintenance and Operating Manual to support the annual testing task:

- The key information from the specification forming the inputs to the project including system description, design criteria and possibly relevant fire engineering requirements in a performance based design.
- The functional control descriptions
- Final system schematics
- Key user intervention actions relating to the operation of the system including clearing of faults etc.
- Inspection test plans for the essential services and critical plant
- Warranties

Whilst the information to be captured in this knowledge model is significantly more than is delivered today by most construction processes it should be noted that the knowledge already exists in the building delivery process and any additional costs involved in capturing this are more likely to be investments in organisation and forethought rather than costs for additional resources.

2.2 Integration of Active Building Services, Passive Design Features and Occupant Behaviour.

Whole System Commissioning

The commissioning of integrated and interdependent systems requires a “whole system” approach as distinct from a functional approach looking only at the operation of systems on an individual basis. Whole system commissioning also needs to be broad in its scope as increasingly the building, including all its active systems, its passive design features and its occupants will become “*the System*”.

It is essential that the designer clearly sets out how systems are to interact. It is not adequate to simply leave it to the installation and commissioning team to sort out the details. At best this will result in systems installed and commissioned to function in isolation with perhaps some limited integration. It is very unlikely to produce a fully integrated, properly performing system.

In the first instance design phase integration across services and packages is primarily a coordination process. The designer should clearly specify:

- The scope of works to be carried out by the trade installer
- The associated works to be carried out by other trades and the builder in connection with the scope of works
- The interfaces and interdependencies between services.

If not properly defined by the designer and managed by the installer issues associated with coordination of services often arise in the commissioning phase where they can have significant impact on the commissioning programme whilst the issue is resolved.

It is often constructive to establish a set of clear guidelines at the outset of a project in relation to the “associated works” and interfacing to assure a consistent approach across all specifications. Examples of these guidelines might be:

- “All signalling cabling is terminated onto a switchboard or equipment by the equipment supplier.”
- “All sealing of penetrations are to be completed by the installer of the service through the penetration.”

The nature of the integration however can change quite significantly, post-practical completion when a building / facility management regime is introduced and the building is occupied. Integration now has to occur between the building services and the occupants. Where occupancy patterns provide inputs to determining start / stop times and load related control this may be relatively straightforward. However when the occupants play a dynamic and active role in building systems control as they can in some types of hybrid or adaptive ventilation systems the integration challenge increased markedly. The Building / Facility Manager has a critical role to play in managing expectations and monitoring the performance of the services.

2.3 The Commissioning Body of Knowledge

Re - Integrating Construction and Commissioning Knowledge

In the last decade the responsibility for producing the detailed design of air conditioning systems and providing stewardship for the installation and commissioning of these systems has generally moved from engineering consultants to the construction team. The understanding of the original designer of the construction and commissioning process has atrophied accordingly along with the understanding of how the designs may be affected and compromised during the installation and commissioning process. The design process has in many cases become “open loop” with little or no feedback to the designers.

We now have a situation where designers are being increasingly called on to produce designs with a real or inferred performance guarantee and are facing substantial challenges in specifying how these designs should be installed and importantly commissioned to achieve the performance outcome required.

This is now highlighting a gap in the industry knowledge base relating to systems commissioning. Whilst guidelines and standards produced by organisations such as the National Environmental Balancing Bureau (NEBB), ASHRAE and CIBSE provide significant information and guidance for specific commissioning activities there is a need for a holistic guideline for integrated systems commissioning.

Such a guide would provide a framework for the integration of systems commissioning throughout the life of a project and into the operational stage of the building. It would capture the commissioning knowledge matrix shown in Figure 4 and would address and interlink the integration of control strategies, installation practices for effective commissioning and system commissioning management and procedures. Ideally such a guide would illustrate a continuous process with information and knowledge flows, check lists and detailed guidance for each stage of the process defining desired outcomes and suggesting roles, responsibilities and methodologies.

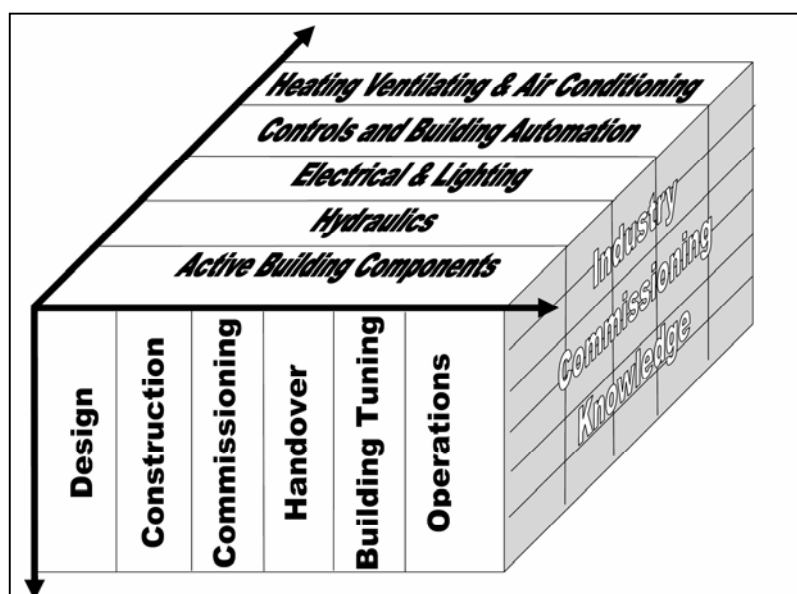


Figure 4. Commissioning Knowledge Matrix

3. CHALLENGES FOR BUILDING COMMISSIONERS

The future will pose challenges and significant opportunities for those responsible for carrying out building commissioning. Energy and environmental building rating systems in particular will drive change in the industry because commissioning skills and knowledge will be drawn into play by these rating systems at every stage of the building's life cycle. Designing to meet energy consumption targets, installation of increasingly integrated and complex systems, introduction of new technology and concepts, commissioning to achieve energy and water usage commitments and other performance parameters, commissioning integrated multi services systems, and structured systems tuning to achieve and maintain star ratings, all will challenge building commissioning specialists to build new skills and apply existing skills in new ways.

The demand for commissioning to grow and develop can be expressed in three dimensions:

Time and Duration of Involvement

The requirement to design and demonstrably deliver a measured performance outcome (e.g. energy and or environmental rating) will require commissioning skills and services to be involved much earlier than they now typically now are, and cause them to stay involved over the life of the building in some shape or form to help keep the building tuned to ensure it keeps its (annually audited) Star Rating.

Technical Skills and Knowledge

Increasing integration of the physics of the building and occupant behaviour with the energy consuming building services, and the increasing integration of these systems themselves will require developments in commissioning sophistication. A more holistic commissioning approach will be required to ensure the achievement of the promised performance levels for the building as a whole. In the first instance environmental rating requirements are now causing the relatively well developed commissioning skills and approaches developed for mechanical systems to be applied to other systems that traditionally haven't been commissioned as thoroughly e.g. lighting, hydraulics (water supply and waste management) and active building systems like operable facades, other natural ventilation systems and active / passive thermal storage systems.

Reporting and Management Skills and Attitudes

The ability of building commissioners to work at different levels and in different ways in projects to what has become the norm needs to be developed. Whether this is at design stage providing input not just on "buildability" issues but also "commissionability" and energy consumption realities, or as part of the installation team that has a responsibility to meet energy targets, or as part of an operation and maintenance service provider team that is required to maintain or better a level of energy and water usage to keep or improve a building star rating.

Some of these developments will come to pass as an evolution of current practices and our industry will grow and better itself accordingly. Others will require the industry to take the initiative to facilitate and drive change.

To meet increasing performance requirements and environmental and energy standards building systems have become more complex and interdependent, and increasingly integrated with the building's physics and the occupant's behaviour. To deliver the required performance outcomes buildings and their systems must now be commissioned with a more sophisticated and integrated approach. Perversely the design and building services delivery process today is much less integrated than it was in the past. Significant changes are required in our approach to commissioning and the development and retention of building knowledge to support the construction of appropriately performing buildings and their continued efficient operation through out their life cycle.

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3. NEBB: *Procedural Standards for Buildings Systems Commissioning*, National Environmental Balancing Bureau
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*About the Authors

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Prior to joining A.G. Coombs he was a Director of a large international Consulting Engineering Group and was responsible for engineering and technical development.

Warwick’s experience ranges from major commercial office buildings and retail centres through to highly specialised Data Centre upgrades. His particular expertise is in central plant design and plant upgrades.

He maintains an active role within the broader industry and is currently a member of the Victorian Committee of AIRAH.

Warwick has been involved in facilitating a range of seminars and presentations relating to energy efficient design, smoke management systems, controls and commissioning.

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He is a Mechanical Engineer and his early work was in guided weapons and defence systems design.

Prior to joining A.G.Coombs Bryon had a 20 year career in engineering consultancy ranging from industrial and transport design through to major project building services design and a range of large scale innovative and award winning energy and building asset management projects.

Bryon currently sits on the Property Council of Australia’s National Regulation Review Committee and is Chair of the Property Councils National Energy and Utilities Committee.

Bryon is also the Chair of the Facility Management Association’s Building Services Special Interest Group.

He is a Fellow of the Institution of Engineers and a Registered Building Practitioner in Victoria.