HMS Queen Elizabeth Aircraft Carrier:

The Challenges and Successes of Commissioning, Trialling and Delivering an Integrated Full Electric Power and Propulsion System.

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Synopsis

HMS Queen Elizabeth (QNLZ), procured by the UK Ministry of Defence (MoD) for the Royal Navy (RN) from the Aircraft Carrier Alliance (ACA), is the first aircraft carrier in the world to utilise an Integrated Full Electrical Power and Propulsion System (IFEP). While building on the design and lessons learned from the UK RN's Type 45 Destroyer, the first front line warship to utilise IFEP, it also presented a step change in size and complexity, not only of the high voltage (HV) electrical power and propulsion (P&P) system and its automation control system, but also the ship's wider distribution, control and auxiliary/ancillary systems, which both rely on and support the HV IFEP. Unlike its forerunner Type 45, QNLZ did not benefit from a full-scale shore-based test demonstrator with the cost/benefit decision being taken to carry the system integration and operational risk into the commissioning and trials phase of the project.

The challenge presented to the ACA P&P Sub-Alliance (comprising Thales, GE Power Conversion, Rolls-Royce and L3) was therefore to develop a commissioning and trials strategy, programme and documentation set that would allow all elements of the IFEP to be set-to-work in as safe and efficient a manner as possible, with the goal of gaining acceptance from the MoD by delivering the required capability to the RN.

This paper will present the methods adopted during this 10-year programme highlighting;

1. The processes followed to develop and then deliver a holistic integrated system commissioning strategy and plan.
2. The pull through and implementation of lessons learned and derisking from previous programmes.
3. The development of the detailed test and trials documentation to allow the P&P equipment and system to be commissioned, trialled and accepted allowing successful delivery into service.
4. The expected and unexpected challenges faced prior to and during the whole-system commissioning and trials phase and what was done to overcome these.

 http://doi.org/10.24868/issn.2515-818X.2018.069

5. The planning and coordination of system integration and sea trials.
6. The lessons learned, successes and best practice that are being taken forward into the programme for HMS Prince of Wales (PWLS).

Keywords: Planning, Integration, Systems, Coordination, Whole-System Approach, Derisking, Power & Propulsion, Auxiliaries/Ancillaries.

1. Introduction:

This paper will present the decisions taken, methods and processes adopted from the early design phases, through early testing, commissioning, setting to work and the trials undertaken both in the basin and at sea allow all elements of the IFEPS to be set-to-work in as safe and efficient a manner as possible, with the goal of gaining acceptance from the client by delivering the required capability to the RN.

It will present the trials and tribulations, and successes of delivering a P&P system considered to be a step change in size and complexity from previous RN vessels. It will discuss the impact of the cost/benefit decision taken to carry the system integration and operational risk into the commissioning and trials phase of the project, where it was known the P&P system would be a critical path to vessel acceptance date (VAD).

The aim of this paper is to highlight experiences considered to be good practice, as well as lessons learned to be carried forward into the final delivery phase of HMS Prince of Wales and for consideration on future naval programmes.

For reference the QEC P&P System is represented in the HV System single line diagram (SLD) in Figure 1.

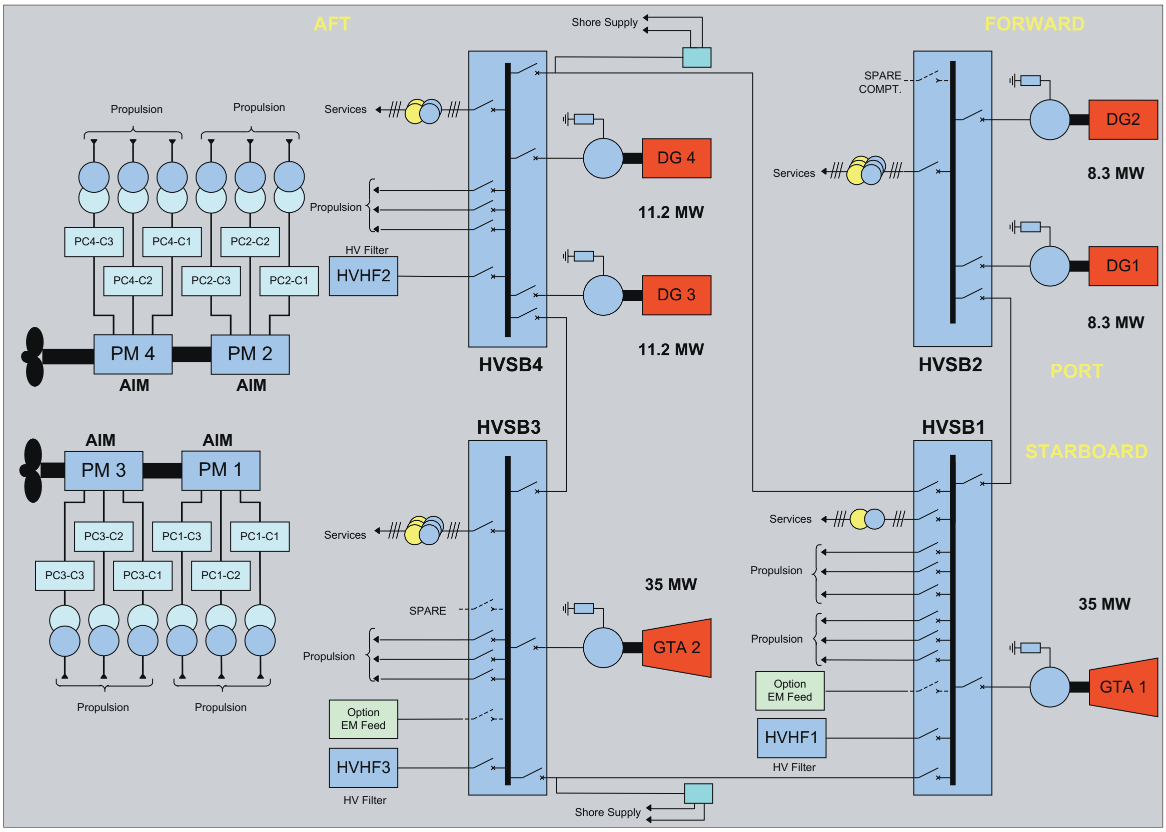

Figure 1: QEC HV P&P System SLD (© QEC Aircraft Carrier P&P Sub-Alliance)

2. Setting the Derisking Strategy

At the start of the project an extensive review was undertaken to capture all the risks that may be encountered during the life cycle of the delivery project. This review looked in depth at mitigation options for these risks, which was developed into a full de-risking strategy [3]. This strategy determined that it would not be cost effective to develop an IFEP system shore based test facility, but time should be allowed for within the programme to encompass an extended system commissioning period in the basin utilising brake blades and a load bank. Thus, achieving a state considered safe to go to sea, whilst recognising the higher power proving would yet to be done.

As part of the whole project strategy to reduce the system integration and operation risks prior to implementation on the ship, several risk mitigation activities were agreed. These included;

- For derisking the twin propulsion motor functional operation, a small scale physical test facility (Labdrive, [2]) was set up, which allowed the functional performance of the propulsion drive to be demonstrated. Matching the Labdrive's mechanical characteristics to the ship's shaftline allowed confirmation that there was no interaction between the drive control and the shaftline mechanical resonance, as well as identifying that the control system could be used to positively affect the mechanical resonance.
- Power system modelling was conducted to assess the steady state and transient performance of both the HV and low voltage (LV) systems.
- To derisk the shaftline installation, the thrust shafts and propulsion motors' couplings were match machined, to remove the need for further machining on ship.
- The gas turbine and alternator were mechanically integrated on the full skid package together prior to delivery to help mitigate the risk of not conducting a full string test.
- To enhance the shore integration facility de-risking the Integrated Platform Management System (IPMS), additional P&P automation systems test was established allowing the controlling software and control hardware operated as per the ship installation. It also allowed proving of the temporary commissioning network and changeover to the final network (ref. section 5).

3. Lessons Learned Capture from Type 45

One of the first activities held at the start of the QE Class (QEC) project was a lessons learned sharing event between the Type 45 (T45) BAE Systems team and the QEC Sub-Alliance team. This covered all aspects of project delivery, including the Installation and Commissioning phases. This allowed key T45 programme experience to be fed directly into the QEC programme, ranging from the importance of adhering to equipment protection during the build and installation phase, the preparation and husbandry of key auxiliary systems, the provision of the necessary facilities and tools for the commissioning of the system, the importance of completing planned shore based testing before going to sea and the need to have a joined-up approach between the different stakeholder teams.

One specific example of good experience on T45 that was flowed through to QEC was the provision of remote, propulsion converter local control panels in an engineering office dedicated to the commissioning team.

4. Early Identification of the Commissioning Strategy

During the early years of the project, to structure the intended approach to the P&P system commissioning and identify the key processes and equipment required to achieve it, a high-level description of the P&P system commissioning strategy was produced [1].

The general principles captured in the strategy were:

- Load banks of up to 19.8MVA for (individual) DG set commissioning at up to 110% load.
- Load bank plus a single propulsion motor for (individual) GTA full power commissioning at up to 110% load.
- Brake blades fitted to each shaftline rated for a single motor at full speed and torque.
- HV shore supply for HV and drive pre-commissioning and uncoupled propulsion motor running.
- HV shore supply used for LV supply after move to non-tidal berth.
- LV shore supply for initial commissioning of up to 4MVA, in dock.
- Parallel commissioning of motors/shaftlines up to coupled running.
- Parallel commissioning of engines/turbines up to HV connection.

This was based on a 'Commissioning Path' approach being adopted by the ACA, to completing the setting to work (STW) of all equipment, compartments and systems feeding into the P&P system.

A baseline commissioning logic was also developed and captured within the strategy, as shown in Figure 2.

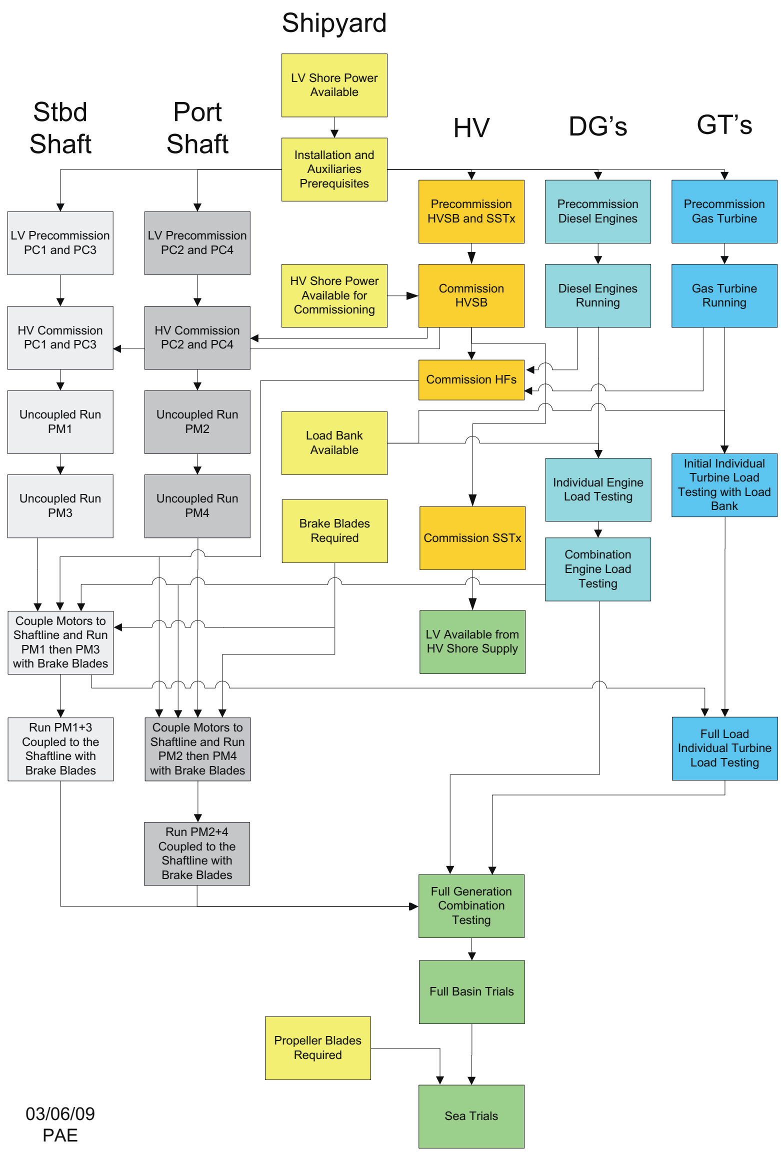

Figure 2: Baseline Commissioning Logic

http://doi.org/10.24868/issn.2515-818X.2018.069

5. Working Together Towards an Integrated Approach & Programme

It was identified that close working relationships would be needed between the SA and the ACA teams to deliver the commissioning programme, therefore a P&P Commissioning working group was set up consisting of representatives from the SA partners, the ACA Commissioning team and the MoD. The aim of the workshops was to agree and finalise the principles of the commissioning strategy (as discussed in section 0) and to develop the P&P commissioning programme. It also allowed organisation structures (see Figure 3), demarcation responsibilities and working relationships to be developed.

From these workshops the role of SA P&P Head of Commissioning was developed, to co-ordinate and facilitate the Sub-Alliance commissioning work to deliver the P&P programme in a timely and cost-efficient manner.

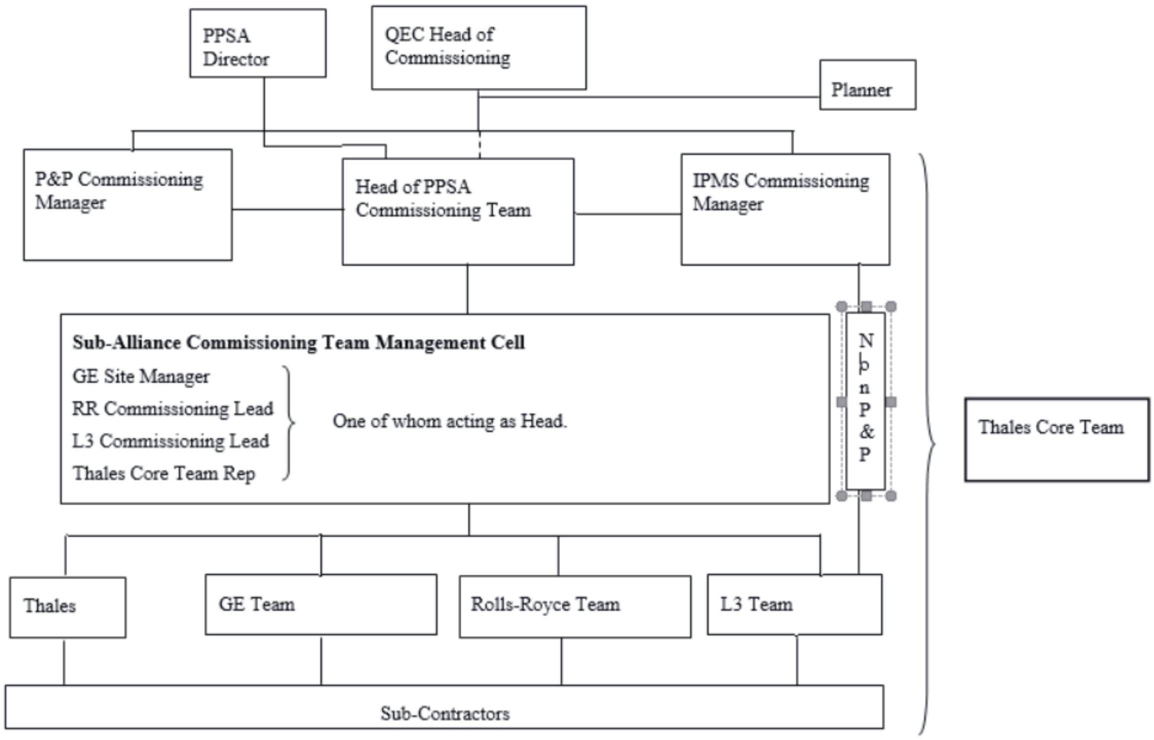

Figure 3: Sub-Alliance Commissioning Team Management Organisation and Relationships

A separate dedicated IPMS Test and Commissioning forum was also set up.

This forum highlighted that the ship's fibre-optic communications network (INE) would not be available to support P&P commissioning and lead to the establishment of a dedicated P&P commissioning network (refer to section 0). The need for and development of a robust software management process to support commissioning was also achieved through this forum.

These workshops provided the basis for the activities discussed in the following sections to be framed and undertaken.

6. Planning

6.1. Creation of an Integrated P&P Commissioning Programme

It was key to capture the activities and timescales required to deliver the P&P system commissioning as early as possible. Each member of the SA produced a stand-alone programme for the delivery of its scope. The HV system commissioning programme pulled through experience from the recent Type 45 first of class (FoC) STW, considering and allowing sufficient time for each key aspect of functionality defined in the High-Level P&P Operating Philosophy Document [4].

A joint activity was then undertaken to integrate each of the equipment focused plans into the overall GE HV P&P System programme, ensuring that all prerequisites and interdependencies were considered, e.g. auxiliary and ancillary systems.

Upon completion the initial programme extended the overall delivery schedule critical path duration, however the collaborative working approach adopted by the SA with the ACA, allowed the strategy to be developed further, bringing key elements of equipment and initial system commissioning earlier in the programme.

The key assumption on which the programme was based, was that all unit test forms for P&P and related auxiliary and ancillary systems and all commissioning paths were completed prior to integration trials commencing.

Ultimately it was possible for an agreed detailed level programme to be produced four years before the original planned start date for commissioning.

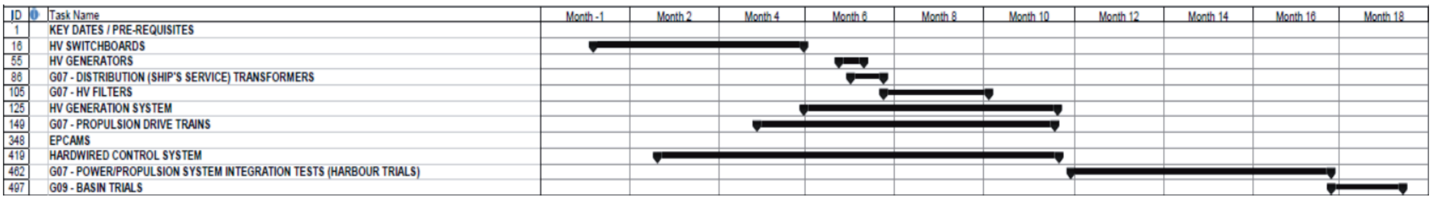

Figure 4: HV P&P System Ship 1 Commissioning Programme (Summary Level)

6.2. Identification of Key Vessel Acceptance Events for P&P System

The vessel acceptance was based on a set of performance events all of which were captured in the ship specifications. This detailed the contractual technical requirements for the whole ship and was extracted into a single document called the Verification and Acceptance Matrix (VAM). For the P&P system within the scope of this paper, this was covered by eight acceptance events, as shown in Table 1.

At the specified ambient temperatures the Integrated Full Electric Propulsion (IFEP) System will continuously generate and distribute the installed electrical generation capacity without the need to limit configuration due to prospective fault currents, and shall distribute sufficient power to propulsion and LV services to meet their concurrent needs.
Power supplies compliant with STANAG 1008 [2] at the user terminals shall be provided for the STANAG loads detailed in Ship Specification 3-6B.
The HV generation system shall demonstrate stable parallel operation in all permitted configurations and power levels under static and dynamic propulsion conditions including system re-configuration, crash reversal & ramp limited activities.
Each shaftline and propeller shall be capable of transmitting/absorbing the maximum continuous rated power/torque from the propulsion motors in order to achieve the speed requirement.
The shaft brake shall be capable of stopping and holding the shafts from the specified ahead or astern ship speed, with propulsion power removed.
The shaftline locking device shall prevent rotation of a locked shaft whilst the other shaft is delivering the maximum achievable full power ahead torque
The system shall stop the ship from its maximum achievable speed, within 15 ship lengths.
MCAS and EPCAMS shall give functional performance as defined in the IPMS sub-system FDS

Table 1 – Key P&P Requirements

 http://doi.org/10.24868/issn.2515-818X.2018.069

The focus was on the quality of the LV power supply during extreme P&P failure conditions, as well the crash stop manoeuvre. Early in the project a document was produced to indicate how the performance of the P&P system could be proven and demonstrated, based on normal operation and during propulsion and power system failures. This document was used to create a modelling package to help understand the system performance, as well as form the basis for the development of the detailed test forms

The full set of P&P test forms consisted of just seven serials, albeit four key TFs were quite lengthy. These four were:

- Propulsion Power Application and Removal.
- Crash Stop.
- Propulsion Machinery Trips.
- Power System Trips.

Throughout the whole sea trial, the power system was monitored using 19 power analysers, one at each HV switchboard and the other 15 positioned at various points in the LV system.

6.3. Identification of expected Sea Trials commissioning time.

Shortly after the completion of the shore based commissioning programme, the ACA released a first draft of a proposed approach to FoC sea trials. This was reviewed and responded to by the SA providing a narrative on how P&P sea trials would need to be undertaken, identifying key dependencies and indicative timescales required for STW & VAM activities. An updated programme was also provided, which remained the basis for the time allowed at sea for P&P activities when the ship sailed over seven years later.

7. Software Configuration & Change Management During Commissioning

It was recognised that changes to software would be required during the commissioning phase. These changes would need to be implemented at pace whilst maintaining configuration control throughout. A process was developed and agreed with the project SME's that allowed commissioning to implement and document most of the necessary changes. Complex code changes were referred to the software development team to implement. At all times the configuration of the installed software was maintained to enable the production of a software version description document.

8. Production of Equipment 'Unit' Test Forms

Unit test forms were developed by the SA team for their equipment based on the ship specifications, system schematics, the manufacturers' operating and maintenance instructions, and hazard analysis outputs. The Delegated Design Authority (DDA) and safety engineer were responsible for the inclusion of product safety information covering all aspects of the safety functions that needed to be tested, which included those required to be proven to meet Lloyds Register (LR) classification rules.

Each test form also identified the parts of the classification rules that needed to be proven and demonstrated to the LR representative.

Test Forms were not issued for use until agreed by the test group.

9. Production of the System Commissioning Test Form (TF)

The initial intention was that two system test forms would be developed, one covering the power system and one covering the propulsion system.

It was recognised, however, that the progression of the commissioning activity would jump from one TF to the other as power system loading and commissioning would progress closely with the propulsion system commissioning. Hence a single TF for the integrated system was developed.

As GE, part of the SA, were to commission the overall system, they undertook the creation of the TF, but it became apparent very quickly that creation of the entire, extensive TF before offering it for review, as per the usual process for TF production, would not be an efficient method. The process used was that the TF would be written in sections and, when considered mature enough, each section was presented to the four signatories in a sub-group meeting format, who reviewed it together line by line.

Amendments were made concurrently during the meeting and generally at the end of each of session, that section of the TF was considered complete. Whilst this process was laborious, it did save time in the review process, with any questions and clarifications being addressed by suitably qualified and experienced personnel (SQEP) at the time.

The following are the section headings under which all elements of the system integration commissioning were captured;

1. Auxiliaries
2. Miscellaneous Control & Interlocks
3. Shore – Ship Power Transfer
4. Coupled Running
5. Power Management System
6. Propulsion Back-offs, Derates, Stops & Overrides
7. Blackout Avoidance & Recovery
8. Fragmentation & Reversionary Control

10. Delivery of IFEP System Commissioning

10.1. The Planning and Coordination of Equipment STW and System Integration Trials.

The intention for the planning of the STW & trials period was for the P&P programme (see section 6.1) to be integrated into the overall ACA integrated project schedule (IPS), which included all aspects of the ship delivery. It was however always expected that the standalone P&P programme would need to be used as the practical method for managing day-to-day activities and progress due to the size and complexity of the IPS. This was proven to be the case.

Coordination of the day-to-day activities was managed in line with the team structure discussed in section 5 but it was also found necessary for there to be significant interfacing between the SA commissioning team leads and the various functional leads of the wider ACA team. For most of the commissioning period there was no overall Integrated Project Team (IPT) structure for P&P, or an overall project team lead.

Throughout the commissioning period issues were encountered. The following key challenges highlight where both anticipated and unanticipated issues manifested and were managed.

10.1.1. Anticipated Challenges

1. Load Testing of Prime Movers
   The load-bank enabled only limited testing of the main generators (as per section **0**) and whilst the load-bank did enable parallel testing of two main DGs at high percentage of their maximum continuous rating, not much of this was undertaken, because the propulsion load produced, using brake blades, provided a much higher load and better dynamic load. The load-bank was principally used to accept the main DGs from Wärtsilä and then to provide a top up load for further testing of the power system.

 http://doi.org/10.24868/issn.2515-818X.2018.069

2. Commissioning Network to INE Transfer
   The introduction of a commissioning network was proven to be a key de-risker as the INE network was unavailable for most of the commissioning programme. The proving of the networks and transfer between them off-ship paid dividends as the final transfer over to the INE was completed with very little disruption to the programme.

3. Planned staged delivery of IPMS for P&P
   To mitigate the staged delivery of the IPMS system element, P&P commissioning activities could be undertaken using EPCAMS and its native P&P human-machine interface (HMI). Therefore, it was possible to make progress in the event of delays in the introduction of the P&P elements of IPMS.

10.1.2. Un-Anticipated Challenges

Implementation Impacts

1. Ship Build Impacts and Miss-alignment of Build and Commissioning Strategies

   Unfortunately, the overall ship-build programme was impacted, resulting in a movement away from the planned P&P commissioning strategy. This resulted in the unavailability of the main equipment due to compartment readiness and the compartment completion inspection programme.
   As the originally planned commissioning path approach was not followed, this resulted in a lack of maturity of compartments, equipment and sub-systems required to support P&P programme. This further impacted the critical path.

2. Auxiliary & Ancillary System Readiness
   Auxiliary and ancillary equipment and systems were handed over to support P&P trials before they were fully set to work, meaning systems were continuously having to be taken offline. This impacted prime-mover availability and the general cooling to the wider system, meaning commissioning activities could not be progressed as planned.

3. IPMS I/O Testing Delays
   Late availability of platform equipment and elements of the P&P IPMS, led to prolongation of the input/output (I/O) testing between IPMS and wider system. Respectively this resulted in late proving of equipment control and monitoring and a degree of I/O testing with EPCAMS alone, which then had to be repeated end-to-end from IPMS, causing disruption and an increase in the planned testing time.

4. Lack of Clear Reporting & Understanding of Overall Programme Progress.
   Due to the flexibility of the system and commissioning teams, it was possible to make some progress, even with the general non-completion of prerequisites, by undertaking whichever activities could be done, but at the expense of efficiency and progress against the planned programme. It became apparent late in the programme that the lack of progress being made due to the immaturity of the rest of the ship and platform systems, had not been clearly reported and/or understood. At the point where P&P trials could no longer continue without full system availability (i.e. initial pre-requisites met) and the actual status was communicated clearly, it led to the highlighting of delays across the whole platform.
   Once the issues had been highlighted it led to a positive cross-team response and joint integration effort to manage the whole P&P programme to completion, which in turn highlighted more significant issues in other areas of the platform delivery. This allowed a whole ship coordinated approach to be adopted for the close out of ship wide commissioning.

Design Related Impacts

1. Misalignment between Hardware and Functional Designs
   Several misalignments between the design specified and implemented for the P&P functionality and the platform hardware were identified, with some causing significant impacts. One key example of this related to the blackout recovery strategy, where there was a gap between the specification of the functional operation of the DG blackstart pump and the actual capability and physical implementation/performance of the hardware installed. As this was only highlighted during the testing of the blackout recovery, towards the end of the system commissioning, the time required to resolve the design and complete additional testing caused a direct impact to the P&P critical path.

2. Spurious Load-shed Initiation

   Unexpected propulsion load shed events were experienced, due to spurious initiation of the load-shed functionality. Investigation of the issue was hampered by the limited amount of P&P trials access. However, a two-day period of P&P primacy allowed the issue to be traced and attributed to signal interference. Actions taken to improve the type and screening of cables internal to equipment did not resolve the issue and ultimately the plant cabling through the ship was changed to provide additional screening. In installing new cabling, additional length was required to achieve the necessary segregation distances, therefore, the issue was considered likely to be due to the segregation not meeting the defined specification and the need for a specific form of screening for the PLC unit used.

10.2. The Planning and Coordination of P&P System Sea Trials.

The original draft ST programme duration was still considered valid. To this the activities outstanding from basin integration trials were added, allowing the P&P plan to be integrated into the overall platform ST programme.

At sea the P&P activities were closely managed between the SA team, the ACA ST management and the RN, with clear rules of engagement being set up early in the trial. This led to a good working relationship between the core commissioning team and the RN marine engineering (ME) and bridge teams, leading to a very successful delivery of P&P commissioning and trials.

There were several issues encountered during the ST which impacted on the availability of P&P trials conditions. The following challenges are identified to highlight where examples of both anticipated and unanticipated issues manifested and were managed.

10.2.1. Anticipated Challenges

1. Ship's Manoeuvring / Platform Trials

   It was expected that coordination of P&P activities with general ship manoeuvring and platform trials would be a challenge. The actions discussed in section 10.2 lead to significantly less disruption than encountered on previous RN platform STs.

2. Mission Systems (MS) Interaction

   While primarily a platform ST, it was expected that MS activities would also be undertaken which might disrupt P&P trials. The upfront planning allowed the necessary priority to be provided to P&P trials conditions and a close working relationship between the P&P & MS teams allowed, where possible, the integration of MS activities into P&P windows on a non-interfering basis.

10.2.2. Un-anticipated Challenges

1. Early use of Propulsion Prior to Expected Use/Commissioning

   The SA team were unaware that propulsion would be utilised before the ship had transited the Forth bridges, however propulsion was used immediately upon exiting the basin to manoeuvre the ship to anchor and later to transit under the bridges. Propulsion was then used up to the maximum allowable power limits without issue during the four-day safety and readiness checks (SARC) period.

   Initial running caused operation at the known mechanical resonance speed, leading to an instability to be experienced. Due to the shore based derisking work (see section 2) it was possible for a real-time temporary solution to be implemented by the GE propulsion expert onboard, with a permanent solution being implemented once P&P commissioning recommenced. The fact that propulsion "immediately worked" highlighted the benefit of the integration trials with brake blades.

11. Lessons Learned

The following are the key lessons learned from the QEC experience;

1. Identification of key risks and methods of derisking them as early as possible in the programme is a must for successful delivery of a complex system.
2. Early development of a holistic commissioning strategy and integrated programme are vital to ensure successful planning and delivery.
3. Engagement between all stakeholders involved in delivery of the platform, not just the commissioning teams, needs to start early in the programme and be maintained through to completion.
4. Design integration alignment is necessary to prevent misalignment between different systems, e.g. hardware and software. Ensure that in addition to direct P&P design owners, all related system owners are fully aware of and aligned with the operating philosophy of the P&P system.
5. Completion of all pre-requisites prior to commencing system integration trials must be given the highest priority to avoid inefficient working and critical path delays.
6. Creation of a cross platform team, with a central point of leadership, is necessary to bring all elements of platform delivery together, to ensure integrated management of the build and commissioning activities and to allow clear direct communication paths between all stakeholders.

12. Implementation of Lessons learned on PWLS

The main change has been the organisational structure to deliver PWLS. This is now a number of Integrated Project Teams operating below the Programme Director. These IPTs cover;

- P&P
- Platform
- Mission Systems
- Operations

The first three are termed delivery teams and each is responsible for the engineering, planning, supply chain, commissioning and acceptance through to vessel acceptance. The operations IPT is responsible for outfit throughout the ship managing the handover of system to commissioning teams and compartment completions.

The planning at a strategic level is more accessible and visible than before, but the real difference is being seen at the tactical level where conflicts between activities in operations, pre-commissioning and commissioning are being identified early and dealt with immediately. Regular meetings internal to the individual IPTs, but including representatives from the other IPTs, are providing the main communication route and the platform for resolution to minimise the impacts.

Detailed planning and management of the individual commissioning paths is helping to drive completion of the pre-requisites. To date this has certainly been evident in progressing the auxiliary systems to support the start of the HV distribution system commissioning, and preparation for first DG starts.

13. Conclusions

This paper has discussed the planning for the commissioning and delivery of the programme, which started in the early phases of the project, involving all the stakeholders both within and outside the P&P SA. It has covered the organisational arrangement and infrastructure that was put in place to help mitigate the anticipated challenges.

Both the anticipated and unanticipated challenges where encountered have been identified, such as; re-planning of ship outfit activities impacting P&P equipment availability and unexpected failures both within the P&P scope and the auxiliary systems. The upfront activities undertaken and flexibility of the IFEP system helped to mitigate these challenges and was the foundation to the success of the whole trials period demonstrating a very stable integrated power and propulsion system with no unplanned total, or partial, electrical failures throughout all the sea trials periods.

Most importantly this paper has captured several lessons some of which have already been implemented into the organisational structure as the project now focuses on delivering the second ship. The integration trials for this ship will take a slightly different course without the use of brake blades and the re-planning and risk assessments to accommodate this decision have commenced.

14. References

[1] – ACA POWER AND PROPULSION TEST AND COMMISSIONING STRATEGY, CVF – 10038972

[2] – Integrating the power & propulsion system for the Queen Elizabeth Class Aircraft Carriers – INEC 2010

[3] – Naval or Commercial Approach to Propulsion Sea Trials Risk - INEC 2006

[4] – QEC P&P High Level Operating Philosophy (Project developed document CVF-10029955)

15. Glossary of Terms

ACA	Aircraft Carrier (Main) Alliance (Thales, BAE, Babcock, MoD)
DDA	Delegated Design Authority
DG	Diesel Generator
EPCAMS	Electrical Power Control & Management System
FDS	Functional Design Specification
FoC	First of Class
GT	Gas Turbine
HV	High Voltage
IFEP	Integrated Full Electric (Power &) Propulsion
INC	(MS) Internal Network Electronics (Ship's fibre-optic communications network)
IPMS	Integrated Platform Management System
IPS	Integrated Project Schedule
IPT	Integrated Project Team
GE/GEPC	GE Power Conversion
L3	L3 Communications
LR	Lloyds Register
LV	Low Voltage
MCAS	Machinery Control & Surveillance
MoD	Ministry of Defence
MS	Mission Systems
P&P	Power & Propulsion
PWLS	HMS Prince of Wales
QEC	Queen Elizabeth Carrier
QNLZ	HMS Queen Elizabeth
RN/RN ME	UK Royal Navy / RN Marine Engineering
RR	Rolls Royce
SA	(Aircraft Carrier P&P) Sub Alliance (Thales, GE, RR & L3)
SARC	Safety & Readiness Checks
SLD	Single Line Diagram
SME	Subject Matter Expert
SQEP	Suitably Qualified & Experienced Person
ST	Sea Trial
STW	Setting to Work
TF	Test Form
Type 45 / T45	Type 45 Destroyer
VAD	Vessel Acceptance Date
VAM	Verification and Acceptance Matrix