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EXPERIENCES AND LESSONS LEARNT ON STAFFING FROM THE FIRST INDIAN NUCLEAR POWER PLANT (PHWR)

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Abstract

Three decades of operating experience in India has led to sustained high performance of NPP's. The staffing modules and policies are standardised. The basic functions of operation, maintenance, technical support and quality assurance are carried out by a team of 727 in-plant persons (for a 2 × 220 MW PHWR station) organised at five levels, for fifty positions in ten job families. Specific qualification levels apply to each position — six at management positions, five licensed positions with the rest qualified through an equivalent training scheme. Practically all O&M activities are carried out on-site by the utility manpower with minimum involvement of contractors. The entire process of human resource development is in-house — with each NPP organisation comprised of 30% experienced staff transferred from older NPPs and 70% totally developed out of fresh recruits. Four to eight years lead time goes to qualify fresh recruits depending on the position. This optimisation of manpower is a result of continuous learning — through operating experience and regulatory feed back and self assessment for (i) optimising quantum of work load and (ii) improving productivity. For the first category, design improvements over older NPP's increased reliability, operability, maintainability and human factors and are described separately in the companion paper. In this paper the organisation factors are discussed, starting with the initial lessons that demanded improved management and enhanced quality programmes and caused temporarily, high demand of staffing for bringing out new systems. For e.g.: (i) attaining maturity of units; (ii) standardising training, retraining and cross training and qualifications; (iii) job rotations; (iv) in service inspection of reactor components; (v) quality audits. The experiences on subsequent optimisation of staffing levels are outlined.

1. INTRODUCTION

Productivity of NPP personnel is a key contributor towards optimising staffing. The motivation for optimisation stems out of the fact that (i) larger the number, larger the risk of human error and (ii) larger number cannot make for lower competence. Assessment and optimisation of staffing is thus, an assessment and optimisation of workload against this expected productivity. The work-load is derived from the activities — both planned as well as unplanned in the NPP, based on which standard staffing levels are worked out. Staffing levels however change with time due to various separations, promotions and induction and management approaches need to maintain the required profile dynamically.

The contribution of design towards optimising staffing has been discussed in a separate paper.

In this paper we narrate our learning experiences since 1972 on the organisational aspects for optimising workload, developing staff competence and maintaining staff profiles.

Table 1 shows the Indian Nuclear Power Programme.

Table 1. Indian Nuclear Power Programme

Unit	Capacity	Remarks
Tarapur Atomic Power Station (Taps - 1 & 2)	2 × 160 Mw	Commercial Oct. 1969 (Bwr)
Rajasthan -1 (Raps -1) Rajasthan -2	100 Mw	Dec. 1973
(Raps -2)	200 Mw	Apr. 1981 (First Of Phwr Program)
Madras -1 & 2 (Maps)	2 × 220 Mw	Jan. 1984 & Mar. 1986
Narora - 1 & 2 (Naps)	2 × 220 Mw	Jan. 1991 & July 1992
Kakrapar - 1 & 2 (Kaps)	2 × 220 Mw	May 1993 Feb. 1995
Kaiga - 1 & 2 (Kgs)	2 × 220 Mw	Under commissioning
Rajasthan - 3 & 4 (Rapp -3&4)	2 × 220 Mw	Under commissioning
Tarapur - 3 & 4 (Tapp - 3&4)	2 × 500 Mw	Under construction

2. INITIAL EXPERIENCE WITH ASSESSING STAFFING

We will outline here our experiences with two major functions:

(i) operations and;
(ii) maintenance staffing.

2.1. Staffing for operations

Operation staffing is determined by manning points and factors depending on:

(i) NPP design, layout, locations and level of automation;
(ii) Regulatory needs of staffing;
(iii) Surveillance testing and maintenance support task;
(iv) Operational routines in the field;
(v) Operational services on site activities;
(vi) Shift structure, number of crews and leave reserve;
(vii) Training requirements.

We will examine here some of the operation factors and experiences.

2.1.1. Manning levels

PHWR's need extra facilities and thus extra manpower e.g. for the following facilities

— D2O additions, deuterations, resin ejections;
— Dryer operations;
— D2 O upgraders & accounting.

Most service systems are run on round-the-clock basis.

Table 2 shows the typical staffing including for control room.

Table 2. Typical shift crew composition in 1982 (raps)

Control room	Field operation (Main systems)	Total
Shift charge engineer = 1	Field engineers = 2	24 per crew
Asst. shift charge engineer = 1	*Operators* – Turbine building = 2 – Reactor building = 2	(9 Engineers & 15 operators)
Control engineers = 3		
Assistant/operators = 2	*Area operators* – Switchyard = 1 – Turbo generator = 3 – Reactor system = 3 – Chillers = 1 – Standby power = 1 – D_2O Upgrader = 1 – Isolations = 1	

2.1.2. Continuing training needs and number of shift teams

Number of shift crews have increased from four to five to six now. Round the clock operation of NPP's on all days of the week including holidays requires at least four teams. However, to cater to sickness and annual leaves of operation staff, as also, to provide for regular on the job training and upgrade training, at least five teams have been in existence since 1987. Each of these five teams comprise of only the minimum manning level per shift as approved and therefore NPP has to draw leave substitutes only from the general shift. In the early eighties e.g. at RAPS, each of the shift team comprised of about 30% more than the minimum shift complement but number of shift teams was limited to 4.5 only.

Operators have a structured training and qualification program and to provide for this lead time (ranging 4 to 8 years for a fresh recruit), an additional strength of total 19 operator trainees was sanctioned at RAPS. Subsequently, based on internal and regulatory reviews, the NPP's implemented the following mandatory practices :

(i) the syllabus and procedures for licensing tests were upgraded which demanded more off the job training time.
(ii) Continuing training focussing on event analyses and refreshers was imparted to each crew.

This led to five shift teams (as against 4.5) without any floating reserve in the team. While this allowed more systematic and planned training activities, the staffing shortages reappeared in most NPP's due to the following reasons:

— transfer of licensed staff to upcoming stations for commissioning and operation;
— enhanced scope of training of shift staff towards good practices, human skills development and management development.

As a result, the number of shift teams has been raised to six with however, reduced manning levels in each team.

2.2. Staffing for maintenance

Maintenance staffing requirements are influenced by

(i) number, type and reliability of equipment;
(ii) maintainability, access and walking distances;
(iii) regulatory requirements of surveillance and tests;
(iv) extent of contracting possible for overhauls, fabrications and repairs.

About 50% of NPP staffing is assigned to maintenance functions. The optimisation of staffing in the NPP basically means, thus, optimising maintenance staff strength without sacrificing safety and reliability. If equipment failures are brought down to a reasonable level the workload and staffing straight way come down.

2.2.1. Workload estimation — issues

Assessing strength of staff in an NPP was not as straight forward as in a project. For example, to calculate number of pipe welders needed in our construction project, the productivity norm roughly could be 250 mm pipe dia per day. For a 2 × 220 Mw unit, the pipe welding workload works out to 1 00 000 metres to be completed in about 3 years; then about 50 welders need be hired. To maintain same amount of piping and equipment the number of welders will have to be worked out however, using a different criteria :

— how many different welding procedures for different metals and techniques exist in the NPP;

— how to keep welders continuously qualified and requalified on their specialised areas of welding during normal operation by mockups and test pieces;

— training needed to work on the equipment with all safety procedures and protective clothings etc;

— redeployability of highly skilled O&M welders through training for their career after attaining age of 45 years when their hand eye co-ordinations are not as before.

In a typical two unit Indian NPP', the principle of assessing maintenance staffing are as follows:

— in the initial stages of NPP, the workload was stated as IP+B with P as preventive Maintenance load and B the breakdown maintenance. As the plant matures with more surveillance the staffing is worked out as 2P+IB. This implies attaining high “Meantime between failures” and low “Mean-time to repair”;

— about 60% of workforce is assigned to " in-situ" or field maintenance duties, 25% on planning and records and rest on workshop (fabrication, tests, calibration, repairs etc.). See Table-3 as a typical illustration;

— staff must be trained and qualified so as to be rotatable from field duties to shop duties or from reactor systems to secondary systems. A token number of tradesmen is also assigned round the clock shift maintenance duties for urgent /routine tasks;

— extent of contracting is limited to only major overhauls.

It is therefore essential that NPP maintenance staff must be managed keeping job rotation in mind. This needs a multiskilling approach in maintenance training and also ALARA provisions and practices.

Table 3. Break up of allocation of maintenance manpower

Sl.no.	Section	% allocation of manpower		
		Field	Shop	Supports
1.	Mechanical maintenance	50 %	25 %	25 %
2.	Electrical maintenance	72 %	20 %	8 %
3.	Instrumentation maintenance	70 %	25 %	5 %

2.2.2. Improved planning for productivity

During 1983–1984, a series of brainstorming, sessions for improving productivity was undertaken by NPP management at RAPS. In the context of manpower in maintenance the following proposals were worked out.

Improved planning

(i) ensure timely availability of work permits (including radiological) by advance application and dedicating operators and HPU staff for the issue of permits. Ensure also receiving of permit, preparations of orders -to-operate (OTO) and conduct of OTO are done in shifts so that isolations are available in day shift : ensure availability at the same time tools, right materials, and protective clothing as also correct mix of crew including riggers;

(ii) store work procedures for repetitive work including time measurement data as e.g. "reactor coolant pump seal replacement";

(iii) improve, by training on supervisory skills the field supervisors and encourage engineers to visit work spot regularly.

2.2.3. In-service inspection

By the late eighties, a standardised, much enhanced in-service inspection (ISI) requirement was documented. The principles laid down for assessment of staffing were as below:

— the work included besides others, ultrasonic testing of all reactor coolant header / piping joints (over 500 nos. above 100 mm dia) in 10 years; similarly in moderator systems. Also eddy current testing of heat exchangers tubes in nuclear systems;
— reactor channel creep thinning, sag and gap measurements;
— special tools and instrumentation development for remote operation.

Even though the group needed highly skilled staffing in sophisticated NDT techniques, the issues that posed challenges were

— absence of suitable vendors with above know-how and with ALARA skills;
— highly skilled staff had to be dedicated to In-service inspection who were fully engaged only during shutdowns. This is so as during normal operations a separate group looked after routine quality control jobs such as welding inspection, welder qualification, pump seal inspection and turbo generator rotor inspection;
— the ISI shutdown jobs also need meticulous dose planning and care to avoid equipment getting contaminated.

It was therefore decided to have an ISI wing and a QC wing under QA/QC group. The ISI group is organised around the specialised skills needed while more interchangeability exists among QC personnel. The following staffing levels are typical:

Engineers = 05

Supervisors = 09

(*technicians*)

Tradesmen = 14

Total = 28

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2.3. Remarks

Based on all above strategies, the operation and maintenance manpower has now been standardised along with other functions.

3. EXPERIENCE WITH HUMAN RESOURCE MANAGEMENT (HRM) ASPECTS

Assessment of staffing levels has to be based on certain productivity of staff and their development of attributes identified as "responsibility", "quality" and "competence". To achieve this goal, the HRM needs to ensure:

— quality of planning;
— quality of training;
— quality of follow up.

3.1. Quality of planning

Good planning needs three inputs:

i. frozen staff strengths and entry level qualifications;
ii. time of placement of identified staff and;
iii. method of recruitment.

3.1.1. Experience in the first PHWR station

During early seventies, the first PHWR two unit station at RAPS was expected to be operated with 342 persons. Table 4 shows that this figure steadily rose to 859 by 1979. In the absence of a standardised staffing level, the constant emphasis was only in inducting new recruits in increasingly large numbers. There was an unattended but burning need to formulate manning norms, recruitment and training policies and develop infrastructure for post-employment training.

An attempt was made to recruit experienced O&M personnel from conventional plants and process industries. As the following statistics shows, the response was poor and the practice of recruiting from open market had to be discontinued in all NPP's. See Table 5.

The reasons why external recruitment was not successful were as follows:

(i) demand of high quality leading to higher standards of recruitment;
(ii) remoteness of the NPP site as compared to conventional industries located in cities or near cities;

(iii) long nuclear training programs with contractual obligations ; fear of over-specialisation in nuclear field with reduced chances for change of job in outside market;
(iv) housing shortages due to presence of large construction workers at peak of their activities.

Table 4. Increasing staffing levels in the first PHWR Station (raps)

Sl.no.	Year	Standard strength permitted	In position	Fresh trainees
1.	1970	342	214	-
2.	1971	342	310	-
3.	1972	342	342	-
4.	1973	500	396	-
5.	1974	500	441	43*
6.	1975	731	548	99
7.	1976	731	650	113
8.	1977	731	679	87
9.	1978	731	705	68
10.	1979	859	742	89

* Stipendiary Training Scheme started.

Table 5. Shows response to open recruitment in 1970

YEAR	No. of applications seeking the job	No. Called for test & interview	No. Attended the test & interview	No. selected	No. joined	Remarks
1970	1029	235	159	46	31	
1971	543	204	153	46	23	
1973	1446	137	66	24	19	

A decision therefore, to build nuclear training centre's (NTC's) and to start in-house induction, training and qualification of O&M personnel out of fresh candidates from colleges were taken in 1974. The scheme, called stipendiary training scheme (for engineers/scientists, supervisors and tradesmen) has been since then the major source of NPP manpower in India. Recruitment planning, as already mentioned, has to be co-ordinated with training planning as per capacity available.

3.2. Quality of training

Nuclear Power Plants (NPP's) need staff with high degree of "responsibility", "quality" and "competence". At any phase or point of time, collectively NPP personnel must have all the skills needed to attain the NPP goals. The human resource development policies are established with a view that future performance will largely be achieved with today's people. The staffing requirements are greatly influenced by the quality of training imparted. Increased emphasis on on-job training, re-training, human factors training and managerial skills development would be possible only if:

- initial training, on the job training and retraining are planned so as not to overload training centres with clear policies on what need to be in centralised training and;
- training resources of simulators, mock ups, manuals and trainer development are planned in advance.

We have now four centralised nuclear training centres and a station training centre at each station. Policies and special training services are provided by the corporate training group including home grown systematic approach to training (SAT) methodology.

3.2.1. Impact on staffing plans

Needless to say, assessment of staffing takes into account that:

- Human resources at all level will be away from job for initial training at other NPPs and continuous training for about two months per year later;
- Dedicated duly qualified trainer and support staff will be needed at each NPP;
- Only after a lead time varying from four to eight years, a trainee will mature as a qualified professional and during this period additional NPP staff for supervising them will be needed.

3.3. Quality of follow-up

Quality of follow-up aims at retention of trained NPP personnel and at maintaining the human resource profile despite changes of separations, ageing and re-deployment of human resources.

3.3.1. Career planning

For retention, certain career policies link individual aspirations to NPP needs:

- Continuous, non-vacancy based but appraisal focussed promotion to higher pay scales for same NPP jobs within a cluster of jobs;
- Additional salary for acquiring licensing based qualifications and career;
- Opportunity to tradesmen and technicians to acquire professional qualifications in engineering and then to obtain higher positions;
- Assistance on science fundamentals to experienced technicians to acquire licensing based qualifications at engineer level;
- Opportunity to engineers to take senior positions in another new NPP or in headquarters.

The idea is not to loose experienced and skilled staff. However, the above do create additional inputs to human resource planning as the profile gets changed by induction from lower levels by promotions as well as by transfer of experienced staff.

3.3.2. Replacements planning

Delays in commissioning of some of our projects, led to loss of young trained professionals - sometimes about 15 in one year. It is hard to replace them, as it takes about four years to get qualified to the first position. Additionally, the tradition of taking large batch of fresh trainees also now create a new problem - of large scale retirement too at one time.

This (retirement) being an age dependent event, it happened to both engineers as well as technicians. Thirdly, certain senior and critical positions are filled in a new NPP only by transferees from older stations, who must be positioned in the new NPP so that they re-qualify for the new position. Simultaneously, replacement trainees in the older NPP must be positioned well in time. Thus, the dynamically changing profile of human resources need to be controlled by close follow up. Some measures adopted by us are:

- train and qualify about 10% extra i.e. over and above vacancies among engineers;
- license and deploy trainees of new NPP in a similar older NPP to also provide temporary replacement of separating transferred staff;
- continuously fill vacancies of technicians and train — no extra staffing is allowed though.

3.3.3. Retention & makeup needs

However, extra staffing does not always lead to required competence, as training and on-job experience opportunities get divided now among larger number of trainees. The only way to make human resource planning effective is to make unplanned separations as low as possible so that make-up needs are either small or predictable so as to avoid negative effects of separations. We have atleast three NPP's with this low-separation feature.

3.4. Remarks

The next section gives the current status on organisation and staffing.

4. CURRENT ORGANISATION & STAFFING

4.1. Organisation

Figure 1 shows the standard qualification based five level organisations for four basic functions:

(i) Operations
(ii) Maintenance
(iii) Technical services
(iv) Training

4.2. Standard strengths

The staff in NPP are categorised as:

(i) Engineers/ Scientists (professional engineering degree holders or masters in science)

(ii) Supervisors (three year engineering diploma holders after twelve years of schooling)

(iii) Tradesmen (ten years schooling plus vocational training of 2 years or twelve years of schooling with science and mathematics)

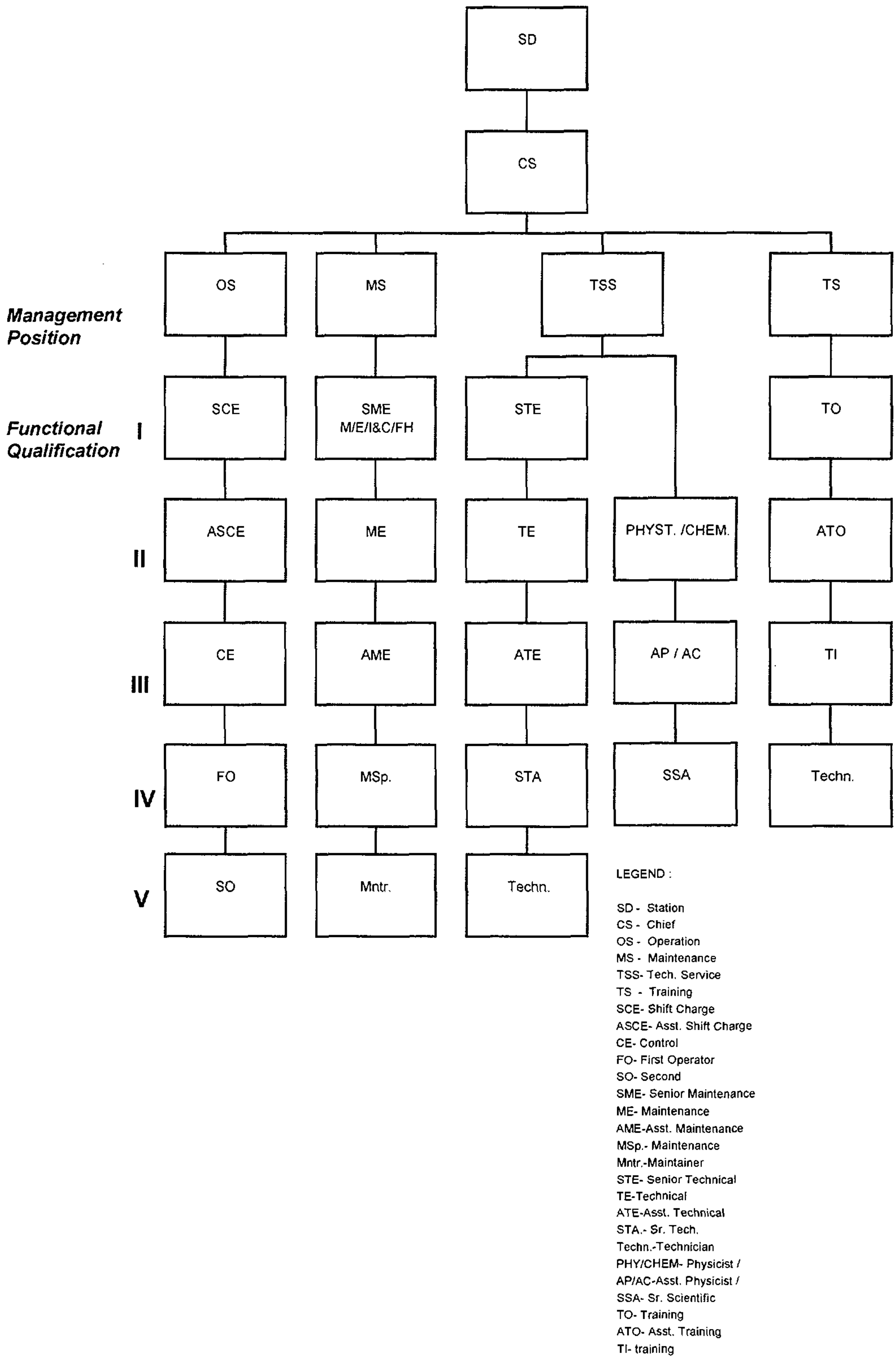

FIG. 1. Operation & maintenance organization.

Table 6 the standard staff strengths by function and category.

Table 6. Standard staff strengths (2 × 220 MW NPP)

Sl.no.	Function	Engineers	Supervisors	Tradesmen	Total
1.	Management	05	-	-	05
2.	Operation	54	30	107	191
3.	Fuel handling	12	18	30	60
4.	Control maintenance	12	18	45	75
5.	Electrical maintenance	10	15	50	75
6.	Mechanical maintenance	15	25	100	140
7.	Technical unit	30	30	20	80
8.	Training	09	06	06	21
9.	Health physics	04	20	20	44
10.	Waste management	01	05	30	36
	Total	152	167	408	727

4.3. Standard recruitment planning

One year, before scheduled criticality of unit-1, 75% of the total technical staffing must be in position. Rest 25% have to be in position before criticality of unit-2.

Source of manpower

Seventy percent of the total strength are recruited as fresh trainees and trained in O&M construction and commissioning activities. Rest 30% positions are manned by transfer of experienced personnel from older NPP's for senior positions as well as from the local construction group.

Lead time of recruitment

Recruitment of trainees must start four years before criticality @ 25% per year. They need to go through intensive induction nuclear training ranging from one year to two years before undertaking on job training for licensing/qualification programmes.

Training capacity

A maximum of 75 trainees, engineers, supervisors and tradesmen at one time, are put on training at nuclear training centre's (NTC's) in different disciplines of operation & maintenance (O&M). This will then not overload the theoretical, practical and field training programmes. Installed training capacity therefore, limits the recruitment size and backlogs are avoided by co-ordinating recruitment with training centres.

Educational qualifications

The new recruit must have entry level standard education such that he can secure the highest level of station qualification in his category. For example an engineer trainee needs to reach up to shift charge engineer /senior maintenance engineer /senior management positions and must therefore, have a bachelor of engineering university degree.

On the job training

Commissioning, operation and maintenance in older NPP's or home NPP's and obtaining licenses and qualification as in Figure 1.

Regulatory requirements

Appointments to management positions, shift charge engineers, assisstant shift charge engineers, control engineers both in main plant as well as refuelling operations are done under direct surveillance of the regulatory board.

For all other positions, the Regulatory board audits the training and qualifications programme for ensuring the competency needs for safe operation.

5. CONCLUDING REMARKS

The experiences from the first PHWR station in India during its initial operation provided valuable feed back for developing competence, improving productivity and retaining qualified human resources. Not only this first NPP attained maturity for subsequent high performance, it also standardised manpower packages for future NPP's. This paper examined the initiatives taken by NPP management towards organisational improvements. The design improvements are narrated in a separate paper.