REQUIREMENTS EVOLUTION FOR THE LANSCE ACCELERATOR MODERNIZATION PROJECT (LAMP)*

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Abstract

The Los Alamos Neutron Science Center (LANSCE) consists of an 800 MeV dual-species (H+ and H-) accelerator serving five separate user facilities, each of which can concurrently receive unique beam delivery patterns tailored for their specific requirements. The LANSCE Accelerator Modernization Project (LAMP) will replace the front-end of the 50-year-old LANSCE accelerator, from ion sources through the end of the 100 MeV drift-tube linac, with the goals of maintaining beam delivery capabilities to all user stations while improving reliability and supporting increased operating hours. These goals drive requirements for the LAMP upgrade project as a whole, and flow down into performance specifications for individual subsystems down to the component level.

INTRODUCTION

In recent years a number of large accelerator user facilities have undertaken significant upgrades and modifications to their facilities. The LANSCE facility is among them: the LANSCE Accelerator Modernization Project (LAMP) [1] will replace the current "front end" of the LANSCE accelerator, ion sources through the end of the 100-MeV drift tube linac.

There are several differences between LAMP and most other projects of similar scale, both in terms of overall scope and of intent. First, LAMP is, as the name indicates, a modernization, not an upgrade. The difference is that LAMP's requirements do not generally incorporate a significant increase in beam delivery performance to the LANSCE user stations. LAMP must, however, maintain existing beam delivery performance to all LANSCE user facilities – concurrent delivery of specifically tailored beam formats to five separate facilities.

Second, LAMP's scope encompasses only a fraction of the LANSCE accelerator complex, specifically the sources through the drift-tube linac (see Fig. 1). It does not include the cavity-coupled linac, downstream beam transport lines,

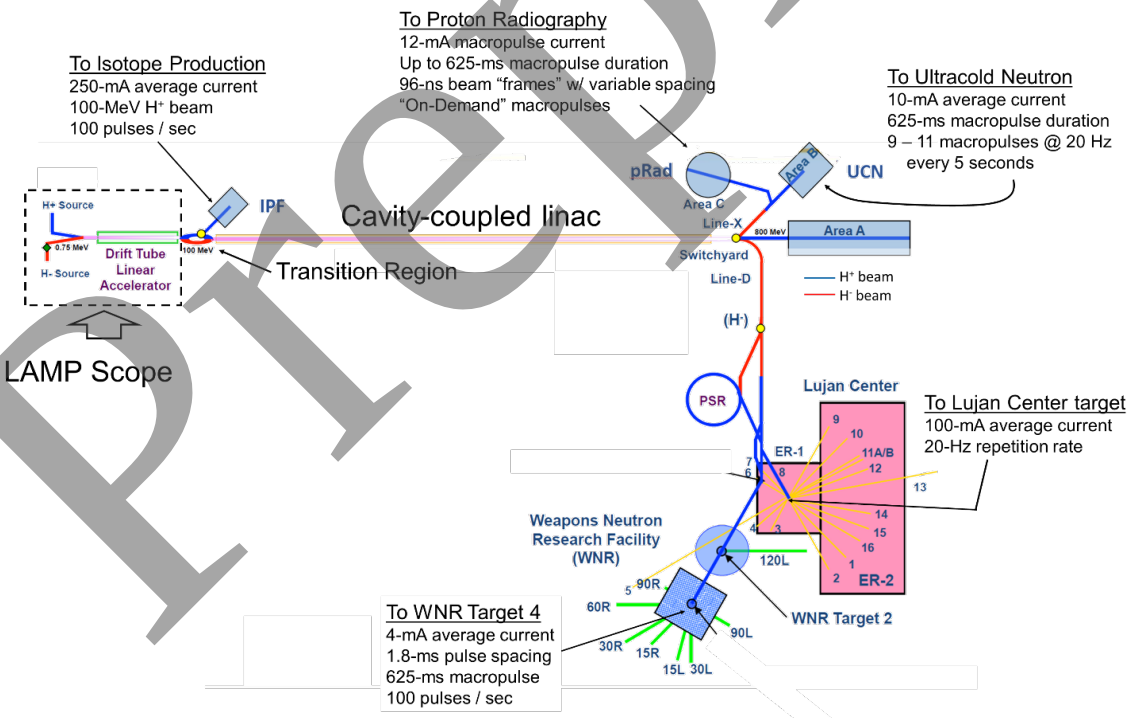

Figure 1: Overview of the LANSCE user facilities, example beam delivery requirements, and LAMP scope.

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or user facilities. Thus, LAMP focuses on the portion of the accelerator farthest from the users. This has implications for translating beam delivery requirements into LAMP accelerator performance requirements.

Requirements for a project can be organized hierarchically. The highest levels of requirements describe the overall performance of the system (e.g. the LAMP project as a whole); lower levels describe the specific requirements of major subsystems, which may in turn be broken down into subassemblies and, ultimately, individual components. Figure 2 depicts a (very simplified) requirements hierarchy along with driving factors, described in more detail below.

BEAM DELIVERY REQUIREMENTS

LAMP's highest-level requirements are set by its Program Requirements Document (PRD) [2,3]. The PRD is a relatively short document "owned" by the funding agency, in LAMP's case the U.S. Department of Energy / National Nuclear Security Administration. The PRD frames most of the high-level requirements and key performance parameters for the project in terms of beam delivery at the various LANSCE user stations, as indicated on Fig. 1.

LAMP's scope, however, only extends to the end of the drift tube linac, or the start of the Transition Region (TR) between the LANSCE DTL and cavity-coupled linac. The beam delivery requirements, as specified in the PRD, must therefore be reframed in terms of beam characteristics and accelerator performance at the start of the Transition Region (TR).

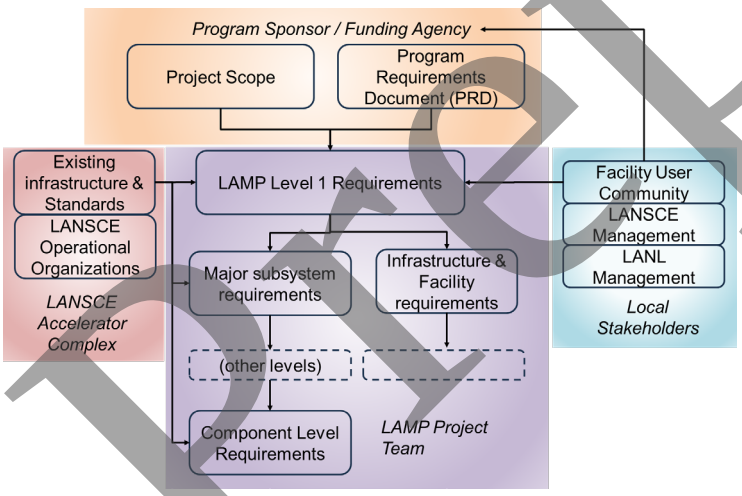

Figure 2: Sources of requirements for LAMP, and illustration of requirements hierarchy.

These "Level 1" requirements are made consistent with the beam delivery requirements as stated in the PRD by incorporating known and inferred performance of out-of-scope systems downstream of LAMP. For instance, historical beam loss rates from the TR to the user facility targets, along with start-to-end simulation, are used to inform target values for beam current and emittance at the end of the drift-tube linac. Machine studies will be performed in collaboration with the LANSCE accelerator physics team to further refine the beam requirements at the end of the DTL.

OTHER SOURCES OF REQUIREMENTS

The PRD, as mentioned above, sets the overall requirements and goals for the LAMP project. Requirements will also arise from other sources, and will manifest at various levels of the requirements hierarchy.

LANSCE User Facilities

Each LANSCE user facility has unique requirements for beam delivery [4]. Parameters such as macropulse repetition rate, bunch train format, bunch charge, allowable dark current, etc. all differ among the facilities; in some cases, such as the Proton Radiography (pRad) facility, the bunch train format must be regularly redefined according to the needs of the particular experiment being conducted. The PRD explicitly provides high-level requirements for each user station; detailed requirements of the user facilities are implicitly included via the mandate to maintain existing beam delivery performance.

LAMP must also not unduly limit other upgrade efforts, either in progress or planned, for other portions of the LANSCE complex.

Existing Infrastructure

LAMP is not a green-field facility; the existing infrastructure represents both physical and performance limitations. Physical limits include existing boundaries of the LANSCE accelerator tunnel and support buildings, along with floor weight loading ratings, and can for example impose requirements on overall LAMP installation length (a higher level requirement), and individual DTL tank size and weight (lower level requirements). The nature and performance limits of major subsystems, such as the existing 201.25-MHz high-power RF plant and facility cooling water systems, impose other requirements on the design of DTL tanks.

The general mandate for the LAMP project is to respect these existing boundaries to the extent possible; thus the existing infrastructure's characteristics must be translated into requirements early in the design process.

Local Standards

Los Alamos National Laboratory has a formalized Conduct of Engineering [5], and specific design requirements for various types of systems commonly found in accelerators. Examples include seismic design standards for support structures; materials selection; electrical system standards for certification; design of pressure systems such as the hydrogen gas supply for the ion sources; and so on.

Finally, LAMP is not a standalone accelerator; it must operate in a fully integrated fashion with the remainder of the LANSCE accelerator complex. The organizations responsible for LANSCE operations and maintenance, such as the Accelerator Operations and Technology division (AOT) and the LANSCE Facility Operations Directorate

(LANSCE-FOD) also provide standards for design, operation and maintenance that must be incorporated into the LAMP design process. These range from personnel and machine protection system standards, to naming conventions for beamline elements, to control system interfaces.

LANSCE USER ENGAGEMENT

Over its decades of operation, the LANSCE accelerator has demonstrated have extraordinary operational flexibility. This has proven invaluable, in general in terms of concurrent beam delivery to multiple user facilities, and in specific instances such as providing uniquely defined beam patterns and timing to pRad experiments. This flexibility has, in recent years, also enabled the facility to continue operation at less than full capacity to either work around faults or to preserve operating capacity for critical experiments.

LAMP is also expected to be extraordinarily flexible in terms of its ability to generate and format beam patterns, but the LAMP "front-end" design – sources to drift-tube linac – is quite different from the current LANSCE configuration. While the "normal" operational parameters of LAMP will mirror those of LANSCE, "off-normal" capabilities – the ability to generate and deliver beams in formats other than standard modes of operation – will differ.

Ongoing engagement with the LANSCE user community accomplishes three critical tasks. First, it ensures that all "normal" operational parameters are captured and integrated into the Level 1 requirements. Second, it allows identification of nominally "off-normal" LANSCE operations that have proven critical to operational success, and should therefore also be incorporated into LAMP's Level 1 requirements. Finally, it assists in communicating the differences between LAMP and LANSCE, both in terms of limitations and in opportunities, to the user community, as the LAMP design evolves.

LAMP LEVEL 1 REQUIREMENTS

Table 1 presents an abbreviated list of the LAMP "Level 1" requirements, that is, what the LAMP accelerator must deliver at the end of the drift tube linac. Please note, the requirements are not finalized, and this list should be considered a "snapshot" as of the time of this writing. Requirements tagged as Key Performance Parameters (KPPs) have both Threshold (not shown) and Objective values. All KPPs must be demonstrated to at least the Threshold level for a project to be considered complete. The KPPs are "locked in" when the project has its performance baseline approved at Critical Decision 2 – approval of performance baseline – which we anticipate in the 2030 time frame.

REQUIREMENTS MANAGEMENT

In addition to being well-defined and achievable, requirements must also have traceability and verification. Traceability refers to the ability to show the origins and basis of a requirement; a requirement's verification method states how the requirement is shown to be met. Verification methods can drive other requirements; for instance, the verification of 100-MeV beam delivery at the end of the LAMP linac, in turn drives a requirement to have a method to determine the beam energy.

LAMP has generated policies and procedures to guide requirements generation and maintenance. The Visure software package [6] has been adopted for LAMP project requirements management. It includes tools for requirements authoring, flowdown tracing (e.g. showing dependencies and traceability both up and down the requirements hierarchy), validation method tracking and test results management.

Table 1: Abbreviated LAMP Level 1 Requirements

Requirement Name	KPP?	Description / Value
Beam energy	Y	100 MeV
Macropulse duration		≥ 625 μs
Macropulse rep. rate		120 Hz
Macropulse avg. current		≥ 16 mA
Macropulse format selection	Y	Species inclusion; H- type (high-I_{amcro} or high-Q_{bunch})
Macropulse structure definitions		H^-: ≥ 5.2 mA I_{macro},
		H^- high-I_{macro}: up to 16-mA bunch train current; up to 2300 bunch trains
		H^- high-Q_{bunch}: ≥ 200 pC/bunch; 1.8 μs between bunches; 1e-5 contrast ratio Q_{dark} / Q_{bunch}
Beam emittance		≤ 0.093 π cm mrad (normalized)
Operating hours	Y	> 5300 hours / run cycle
Availability	Y	> 90% of scheduled op. hours

CONCLUSIONS

The LAMP project at Los Alamos National Laboratory will modernize the upstream portion of the LANSCE accelerator, from ion sources through the end of the 100-MeV linac. Requirements development for the project includes translating requirements for beam delivery at the user stations, to beam performance at the exit of the 100-MeV LAMP linac, as well as incorporation of local standards and procedures, limitations imposed by existing infrastructure, and the need to provide comparable beam delivery flexibility to the original LANSCE front-end.

Requirements are being collected, managed and refined using the Visure software tool.

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