ALS-U SR MODULES PRESTAGING PLANNING TOOL AND METHODOLOGY

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Abstract

The Advanced Light Source Upgrade (ALS-U) project faces strict schedule requirements demanding rigorous planning of manufacturing assembly activities well in advance of assembly and installation. Delays of module components, and changes to the module tunnel installation sequence may significantly impact the module assembly (Prestaging) schedule for all 48 Storage Ring (SR) modules and therefore the installation of those modules during the 9-month SR removal and darktime installation period. To assess the adherence to schedule requirements, Prestaging developed a Visual Basic for Application coded planning tool to automate estimation of SR module assembly duration and resource needs. The tool methodology is based on bottom-up task sequencing where individual assembly tasks are laid out in succession with adjustments made for resource constraints and equipment conflicts. The model processes schedule and resource needs across 5 resource types for approximately 35 assembly tasks per module, generating duration estimates and resource profiles for SR module production. Functional testing has demonstrated the tool's capability to reduce planning time from approximately 4 hours of manual work per scenario-to-scenario processing to minutes while reducing inherent human error. With the model, Prestaging can quickly react to module component delays ensuring assembly planning is optimized within the constraints of the project. This contribution describes the model development methodology, functional testing results, and applications for future use during the ALS-U module assembly phase.

INTRODUCTION

During the 9-month darktime installation period, the existing ALS storage ring will be replaced with the new ALS-U storage ring [1]. To expedite the installation of the ALS-U SR, the 48 discrete modules that comprise the ring will be preassembled outside the tunnel by the Prestaging group [2]. Each module is comprised of magnets, vacuum chambers, LCW lines, support features, compressed air lines, electronics, and cabling [3]. It's the role of Prestaging to streamline the module assembly procedure, optimize the module assembly space within preexisting facility constraints, and perform functional tests on the module prior to installation.

The Prestaging assembly plan faces various challenges;

- Assembly spaces are limited to the existing LBNL facilities.
- Investment into the facility or assembly equipment must be justified by resource and assembly time schedule improvements.
- Module component delays were expected based on experience from previous assembly phases and tight procurement timelines.

The planning tool is a macro which generates a Gantt chart of assembly steps for each module in the production schedule with adjustments made for resource overallocation. Another output is a resource chart which sums personnel resource groups needed by week. The macro's outputs had to be considered along with a qualitative assessment of material storage, logistics, and risks to determine the most efficient assembly strategy that meets schedule constraints.

The macro was developed in support of two planning phases; the first to determine what facility equipment investment and resource allocation minimizes production duration, the second to optimize the assembly sequence within the equipment and facility constraints as determined in the first phase.

MACRO DEVELOPMENT PHASE 1 : FACILITY AND EQUIPMENT CONSTRAINT DETERMINATION

Tool development began with a breakdown of the assembly sequence for one module. Prestaging stakeholders (Prestaging, subsystem engineers, and technical support groups including mechanical and electrical tech teams, and Survey & Alignment) reviewed the module assembly design documentation and developed a baseline assembly process. The baseline assembly process identified 35 assembly steps, established assembly component sequence dependencies, equipment and personnel resources, and the estimated working duration for each assembly step.

Adjustable variables were built into the macro so the number of shared resources could be modified each time the macro was run. The Prestaging team toggled these production variables and iterated running the macro to produce unique outputs for each variable configuration. A comparison of the iterated Gantt charts provided insights into which features had the greatest impact on the production schedule.

Case Study 1: Crane Investment Optimization

Figure 1 graphs the overall production duration against 2 variables, the number of cranes and the number of Prestaging assembly stations. Multiple cranes mean assembly steps that require a crane can be performed on different modules in parallel.

The maximum number of stations that could fit in the Prestaging areas (High Bay 1 & High Bay 2) is limited to 10.

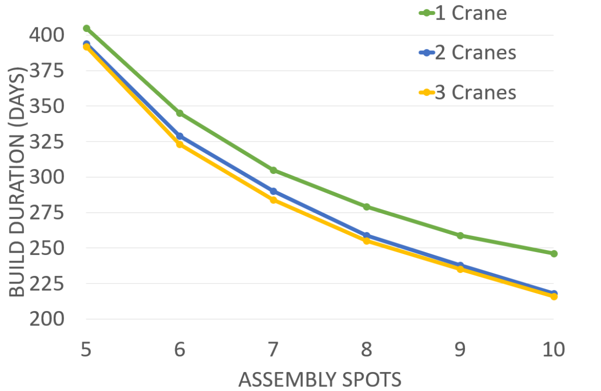

Figure 1: Graph of Prestaging stations vs Prestaging build duration.

There is a reduction in Prestaging production duration by increasing the number of assembly stations (number of modules which can be assembled in parallel). The graph also provides evidence that there is negligible advantage to using 3 cranes instead of 2 cranes. Investment in 2 cranes is valuable, investment in 3 cranes is not.

Case Study 2: Macro Output Analysis

Principally the macro outputs two graphs, a timeline with a simplified version of the Gantt chart and a personnel resource chart by assembly week. Examples of these outputs are shown in Fig. 2 & 3. Option A assumes 6 modules are assembled in parallel with all assembly steps planned in one location (High Bay 1).

The Option A timeline (Fig. 2) displays the schedule where each cell is a day, each row is a module, and the assembly steps are grouped into 3 broad groups (initial assembly in green, alignment in blue, & final assembly in orange).

The white cells represent module inactivity. Mainly white cells occur before module assembly starts or after assembly completes. There are 44 rows to represent the 44 modules in production (4 modules are assembled during the first article period and are not in the production schedule). The black squares in the timeline represent times when module assembly is paused because a facility resource (crane, crawler, temperature room availability) has reached capacity. The large delay at the beginning of Option A production is due to crane overallocation, caused by the assumption that assembly on all 6 modules begins on the same day. The total assembly duration is 386 working days (77 weeks).

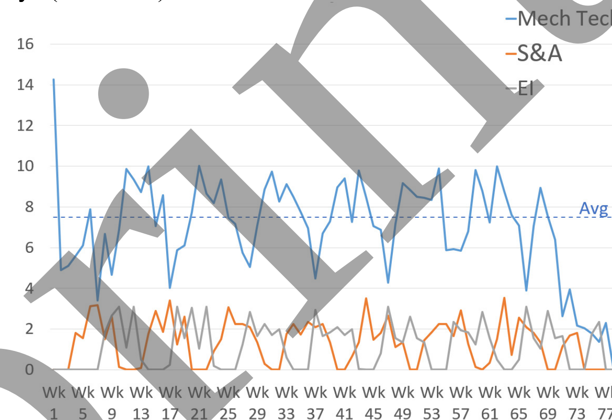

Figure 3: Option A personnel resource graph.

The personnel resource graph (Fig. 3) displays the personnel resources required to support the production schedule by week for the Mechanical Technicians (Mech Tech),

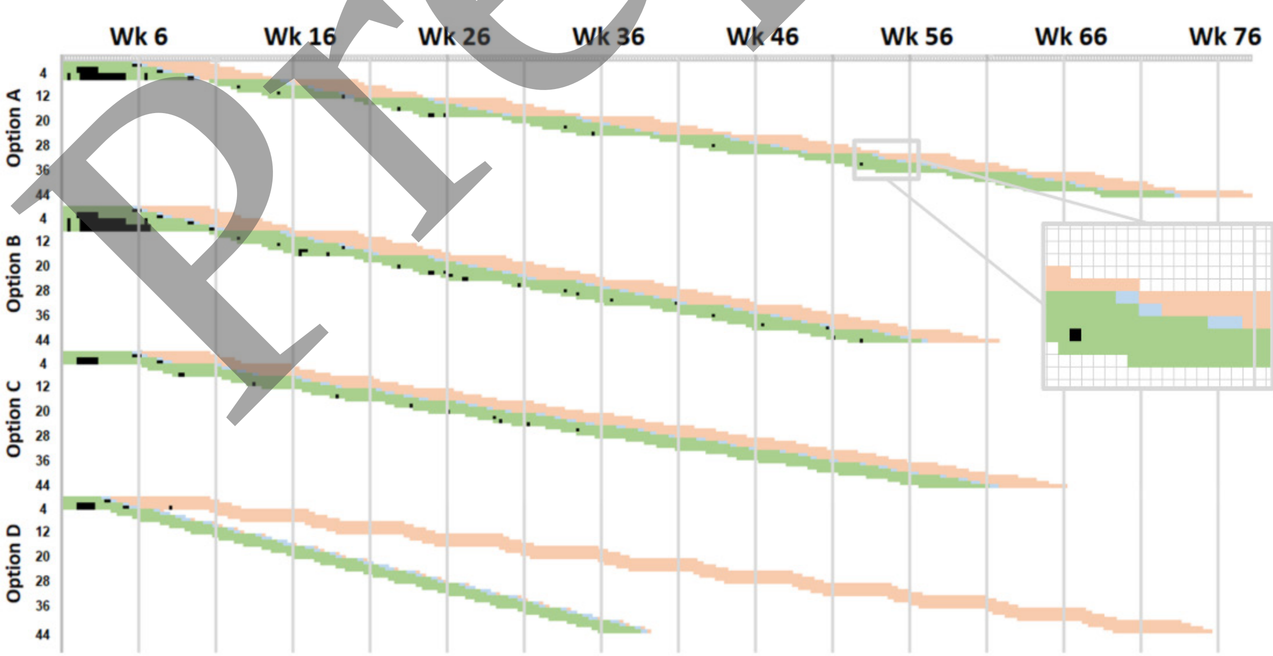

Figure 2: Production option timelines compared.

Survey & Alignment team (S&A), and Electrical Technicians (EIs).

The production average provides the baseline estimate for required resources. The average mech tech requirement for Option A is 7.5 technicians per assembly day. The macro does not have the ability to level resources but interpreting the graph can give some insights into areas for optimization. For instance, the mech tech spike at the beginning could be resolved by staggering the first few module assemblies or planning more technicians specifically at the beginning of production.

Case Study 3: Assembly Station Location Comparison

As demonstrated in Fig. 1 the number of assembly stations directly correlates to the production assembly duration. Maximizing the number of assembly stations and optimizing the location of those assembly stations became a critical consideration for macro analysis.

Option B assumes 8 modules assembled in parallel with all assembly steps planned in one location (High Bay 1). Option B adds two assembly stations in High Bay 1 (compared to Option A) and consequently reduces production to 304 working days (61 weeks, see Option B in Fig. 2). The crane over-allocation at the beginning as represented by the black squares is worse than Option A as more modules are started on the first day.

The addition of assembly stations also drives an increase in personnel resources. The average mech tech requirement for Option B is 8.9 technicians per assembly day.

By comparison Option C also assumes 8 assembly stations but splits assembly operations between 2 high bays. The timeline for this option is shown as Option C in Fig. 2. Initial assembly & alignment (green & blue) is performed in High Bay 1, final assembly (orange) is performed in High Bay 2.

Option C assembly duration is 326 working days (65 weeks). Splitting the assembly between the 2 locations has reduced the early over-allocation issues but extended the overall production duration compared to Option B.

At first glance Option B is more appealing. A shorter build duration is better equipped to meet the module installation schedule. However, there are assembly factors outside the scope of the planning tool that need to be considered in addition to the overall duration and resource estimates. A short production build is less flexible to component delays. Spreading the assembly work between high bays also means component storage is available near the assembly stations, reducing the material planning complexity and in turn the resources required to transport or manage component availability in the assembly area.

MACRO DEVELOPMENT PHASE 2 : ASSEMBLY OPTIMIZATION & PROCESS VERIFICATION

In the second phase of macro development, the ability to toggle production variables was removed from the macro and the baseline assumptions, as determined in the first phase, became constraints. Within those constraints Prestaging continues to optimize the production schedule by validating the equipment, personnel, and duration estimates with first article components and modifying the assembly sequence for time saving opportunities.

Case Study 4: Assembly Sequence Modification Impacts

The module component assembly sequence can have a major impact on the overall production schedule. In Option C of Fig. 2 the alignment step (in blue) depicts the alignment of module components and demarcates initial assembly in High Bay 1 and final assembly in High Bay 2. If the assembly sequence is modified such that alignment is performed earlier in the timeline (as shown in Option D of Fig. 2), final assembly in High Bay 2 lasts longer compared to Option C because more assembly work is performed in High Bay 2.

The white squares in-between the diverging graph of Option D in Fig. 2 represent the time when a module cannot progress from High Bay 1 to High Bay 2 due to lack of assembly space. The total production duration for this option extends to 373 days (75 weeks).

A meaningful takeaway from Option D is that when the production duration between the two high bays is unequal, the high bay with a longer duration is a bottleneck for module throughput. The assembly duration should be equal between the two high bays to optimize throughput. The planning tool cannot model the risks associated with performing alignment earlier in the sequence, when fewer components are mounted to the module, but risks are a necessary consideration when modifying the assembly sequence.

CONCLUSION AND NEXT STEPS

The planning tool has run over 200 planning scenarios saving over 800 hours of evaluation time. As production approaches the planning tool continues to provide planning feedback as assembly steps are validated on first article hardware. The macro estimates are regularly revised and the Prestaging schedule adjusts to account for delayed subsystem hardware. The tool will remain valuable as it provides needed flexibility for Prestaging to actively adapt to evolving project variables to optimize the production schedule for the ALS-U SR installation.

REFERENCES

[1] D. Leitner *et al.*, “Removal and Installation Planning for the Advanced Light Source - Upgrade Project”, in *Proc. IPAC'19*, Melbourne, Australia, May 2019, pp. 1609-1611. doi:10.18429/JACoW-IPAC2019-TUPGW088

[2] C. Steier *et al.*, "Design and construction progress of ALS-U", in Proc. IPAC'24, Nashville, TN, May 2024, pp. 1313-1316. doi:10.18429/JACoW-IPAC2024-TUPG38

[3] D. Gudkov *et al.*, "Design and Integration of ALS-U Storage Ring Modules”, presented at IPAC'26, Deauville, Normandy, May 2026, paper TUP2343, this conference