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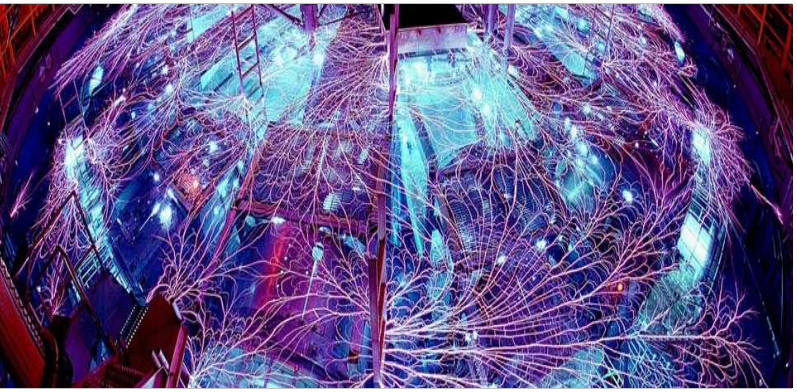

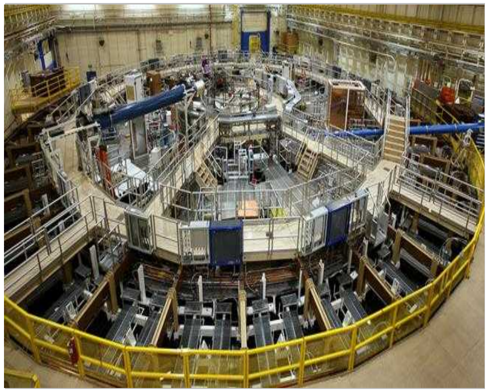

Implementation of Lean Tools in a Scientific Research and Development Facility

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Outline

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Sandia National Laboratories

- Sandia National Laboratories located in KAFB in Albuquerque NM, is one of the Department of Energy's (DOE) National Nuclear Security Administration (NNSA) laboratories.
- Sandia National Laboratories' roots lie in World War II's Manhattan project, which built the world's first atomic bombs. Although Sandia originated as a single mission engineering organization for the non-nuclear components of nuclear weapons, today it is a multi-program laboratory engaging in research supporting a broad spectrum of national security.
- Their primary mission is to develop, engineer, and test the non-nuclear components of nuclear weapons.
- Sandia is home to a wide variety of non-nuclear weapons program research, including computational biology, mathematics (through its Computer Science Research Institute), materials science, alternative energy, psychology.
- Sandia formerly hosted ASCI Red, one of the world's fastest supercomputers until its recent decommission, and now hosts ASCI Red Storm, originally known as Thor's Hammer.

Z Pulsed Power Facility

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- The Z facility is the largest pulsed power facility and x-ray generator in the world. Z's ability to generate an electrical pulse of 26 million Amperes with an electrical power of 100 trillion Watts enables it to produce intense magnetic fields far higher than any other device on earth.
- Z provides critical data for weapon primaries, secondaries, and non-nuclear components as part of the NNSA's Stockpile Stewardship program.
- Z is also essential for evaluating the feasibility of obtaining fusion energy with pulsed power.
- As with most national laboratory facilities, the atmosphere is heavily dependent on research and development activities. The facility must be both flexible and robust in order to accomplish national experimental goals.

Problem Statement

- The Z Pulsed Power Facility, along with other Sandia facilities, is facing many challenges with funding. The facility is expected to **Increase** or at least maintain the number of experiments completed each year, while obtaining high quality data, with **Fewer Resources** available than in prior years.
  - As a result, Lean Six Sigma methodology needs to be considered to identify the current situation, define a future state, and generate detailed steps to be followed in order to reach these improvements.
- In this particular environment (i.e., Scientist R&D), in which finished goods are not produced, our product is the data created and collected from every experiment. Therefore, we must focus our efforts to improve the data production and collection while we eliminate any sort of waste in every department that interacts with the Z facility.

Research Objectives

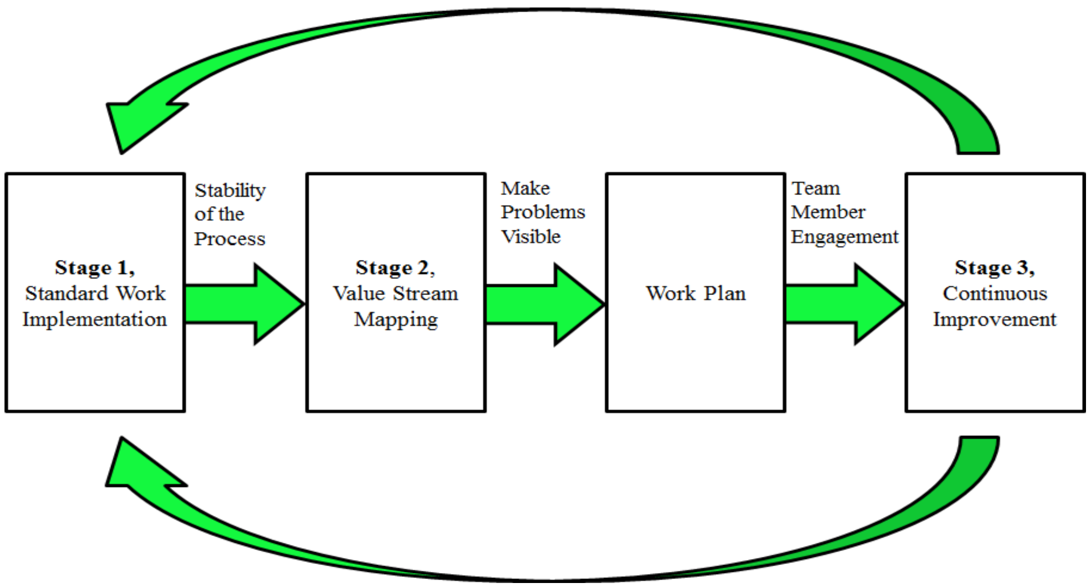
- The main goal is to apply "**Lean**" concepts in a "**Scientist R&D**" environment to improve the effectiveness and efficiency of the operations.
- For **effectiveness**, the emphasis is on standardization to ensure that the current operations are done in a correct way. The mission is to develop several flexible and efficient standard work sheets for every department. The purpose of these worksheets is to standardize the work and identify jobs that change every day so that they can be analyzed differently.
- For **efficiency**, the emphasis is on identifying opportunities for continuous improvement. The mission is to map the process of a regular day at the Z facility, using lean tools such as value stream mapping (VSM) in order to aid management to better understand the processes and to identify improvements.

Literature Review

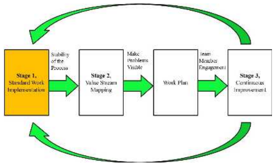
- Standardized Work
- Process Mapping
  - Flow Chart
  - Value Stream Mapping (VSM)
- Critical Path Method (CPM)
- Cause and Effect Analysis
- Total Productive Maintenance (TPM)

Methodology

- This case study develops a theoretical model focuses in **Two** separate dimensions of potential improvements in R&D laboratories: effectiveness of the operations and efficiency of the system. In order to achieve these improvements, a **Three-stage** implementation plan of Lean and Six Sigma has been developed.
  - Stage 1, Standardize the Process
  - Stage 2, Identify Non-Value-Added Activities
  - Stage 3, Continuous Improvement of the Value Stream



Stage 1, Standardize the Process

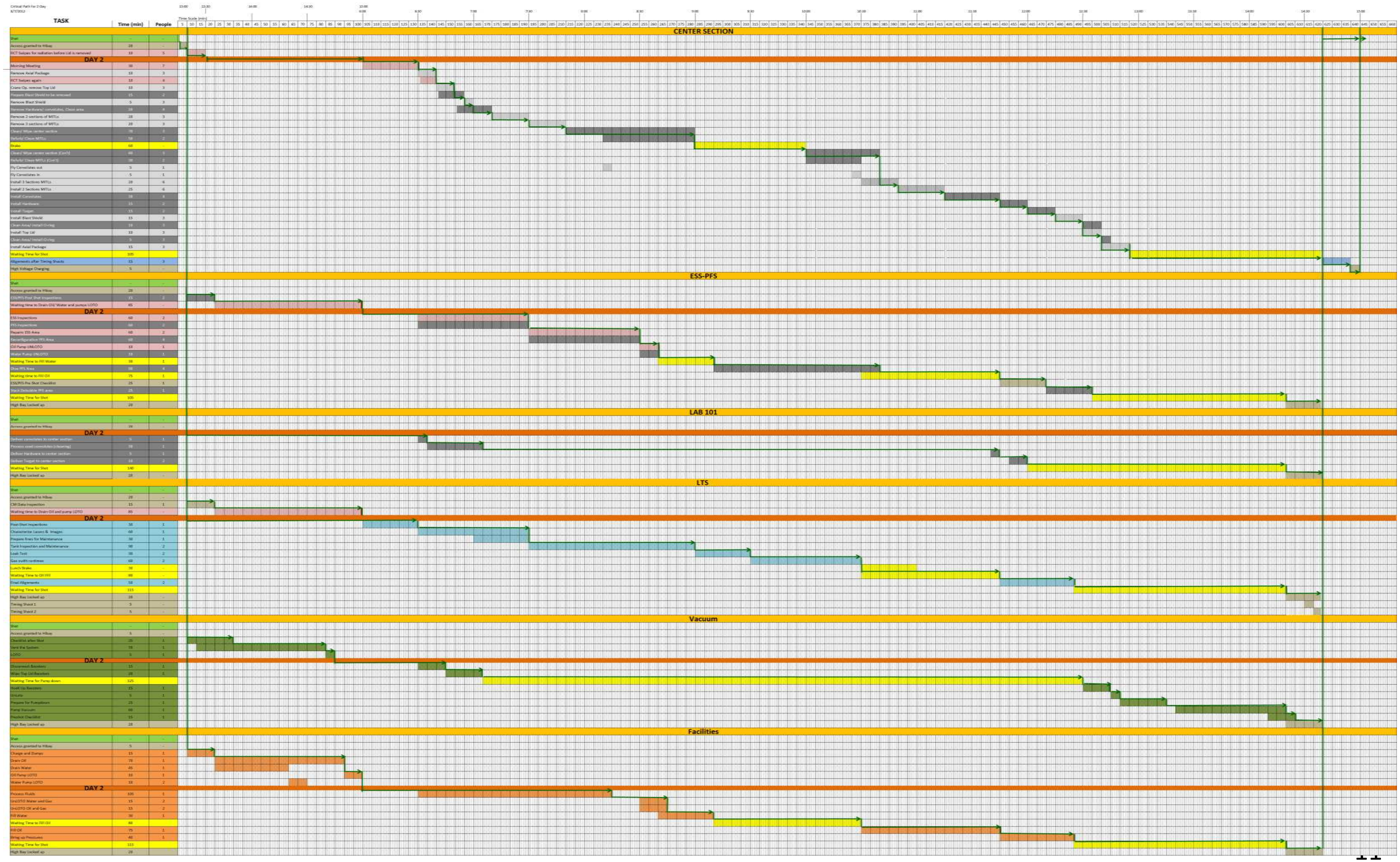


- The first phase, focuses on improves the effectiveness of the operation by the implementation of standardized work; standardized tasks are the foundation for continuous improvements and employee empowerment.
- Establish standards, systems, and procedures to maintain the standards through problem solving and deviation. When this standard is achieved on a consistent basis, the next more challenging standard is established, resulting in continuous improvement of the organization (Morgan and Liker 2006).
- The emphasis is given in standardization of operations by creating worksheets and checklists for every department that interacts with the main facility. One must standardize, and thus **Stabilize** the process, before continuous improvements can be made.
- Therefore, the first step to move toward lean implementation, is to identify the critical path of the process and those tasks that can be standardized.

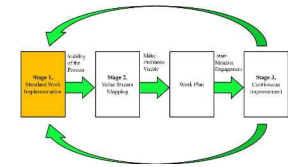
Departments at the Z facility

Department	Supplier	Customer
Center Section	Hardware Lab, Vacuum	Control Monitor
	Radiological Control Technician	Vacuum
	Control Monitor	
Energy Storage Section (Oil)	Data Acquisition Section	Laser Trigger System
	Laser Trigger System	Data Acquisition Section
	Facilities	Facilities
Pulse Forming Section (Water)	Data Acquisition Section	Control Monitor
	Facilities	Data Acquisition Section
		Facilities
Radiological Control Technician	Control Monitor	Center Section
	Data Acquisition Section	
	Center Section	
Hardware Lab	MANAGEMENT	Center Section
	DESIGNERS	
Vacuum	Center Section	Control Monitor
	Control Monitor	Data Acquisition Section
Control Monitor/Data Acquisition Section	EVERYONE	EVERYONE
	NOT Hardware Lab	NOT Hardware Lab
Laser Trigger System	Energy Storage Section	Energy Storage Section
	Data Acquisition Section	Data Acquisition Section
Facilities	Energy Storage Section	Control Monitor
	Pulse Forming Section	Data Acquisition Section

Z Departments Time Description



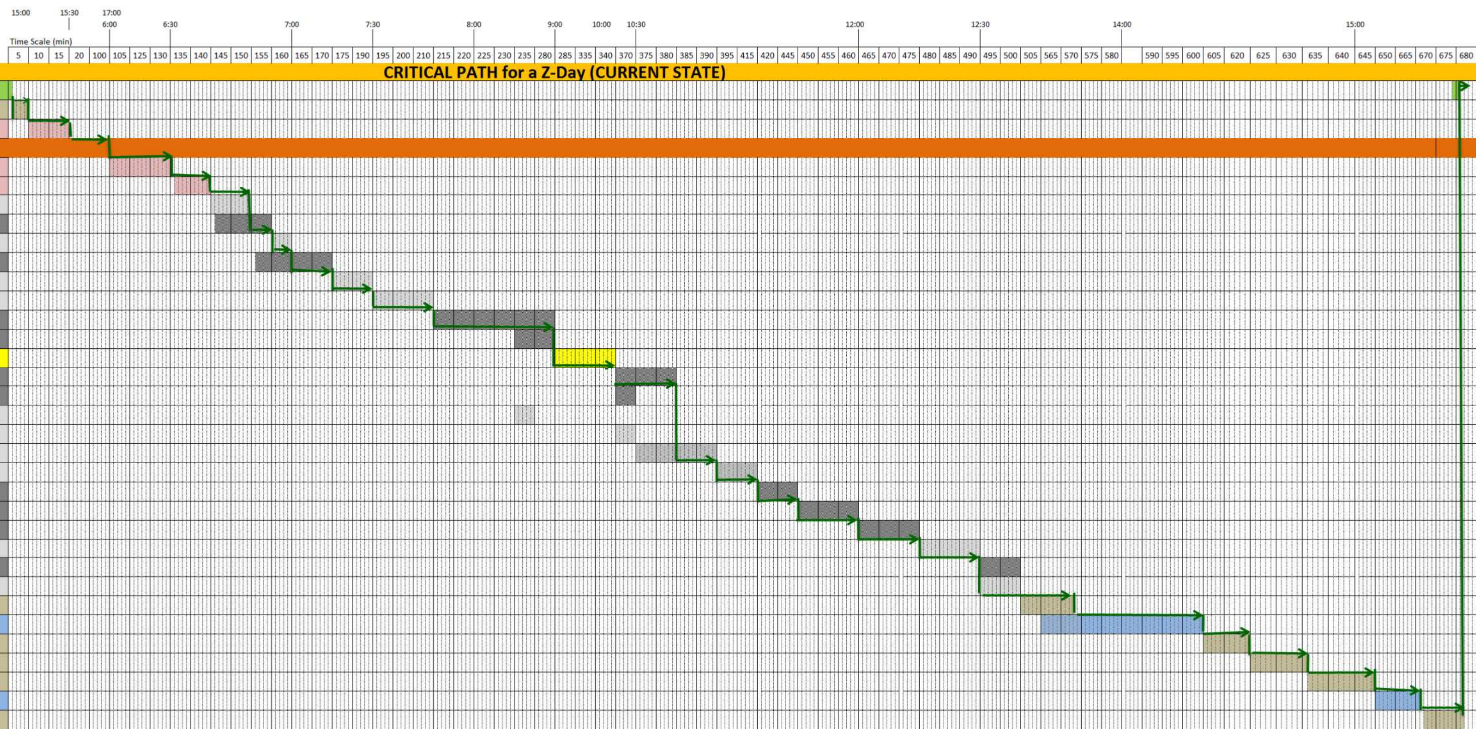
Stage 1, Critical Path



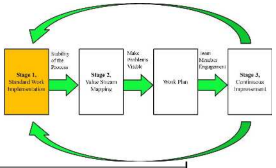
- This Table represents the critical path for a regular day at the Z facility from shot to shot. The time determined for every task is on average taken from up to 20 days of capturing information at the facility.

Critical Path for Z-Day
8/7/2012

TASK	Time (min)	People
Shot	-	-
Access granted to Hibay	25	2
RCT Swipes for radiation	10	5
DAY 2		
Morning Meeting	30	?
RCT Swipes again	10	4
Crane Op. remove Top Lid	12	3
Prepare Blast Shield to be removed	15	2
Remove Blast Shield	5	3
Remove Hardware/ convolutes, Clean area	20	4
Remove 2 sections of MITLs	21	3
Remove 3 sections of MITLs	23	3
Clean/ Wipe center section	70	3
Refurb/ Clean MITLs	65	2
Brake	66	-
Clean/ Wipe center section (Con't)	41	3
Refurb/ Clean MITLs (Con't)	31	2
Fly Convolutes out	5	1
Fly Convolutes in	5	1
Install 3 Sections MITLs	20	6
Install 2 Sections MITLs	23	6
Install Convolutes	30	4
Install Hardware	20	2
Install Target	18	2
Install Blast Shield	8	3
Clean Area/ Install O-ring	10	3
Install Top Lid	10	3
Pump Vacuum	67	1
Final Alignment after Vacuum	40	4
High Bay Locked up	20	3
Timing Shoot 1	12	2
Timing Shoot 2	15	2
Alignments after Timing Shoots	22	3
High Voltage Charging	12	1



Stage 1, Proposed SWS



Standard WorkSheet

Facility: Z Accelerator	Area / Dept Center Section	Page 1 of 1	Code: SWS -001	Effective Date: Expiration:	Author: Review by: Accepted by:

Unload-Refurb-Install MITLs, Hardware, Target, Top Lid

Takt Time:	404 MIN
Parts per Hour	0.15 PARTS/ HR

Tools Required

*Crane
*MITLs Flipper
*Cloth Wipes
*Air Guns
*Hand Brushes
*Torque wrenches
*Halogen Leak Detector
*Calibrated SF6 leak
*3-legged chain bridle sling

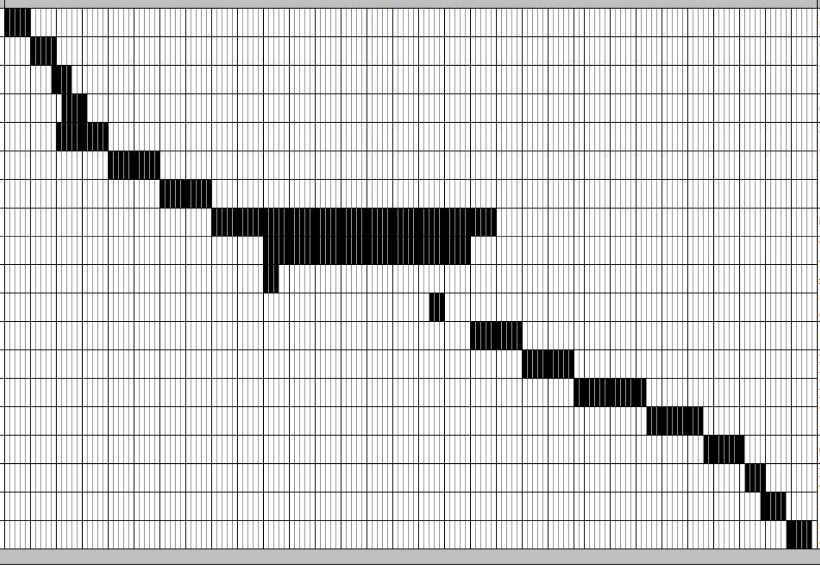
Safety Equipment

- Safety Shoes PPE	Tyvek coveralls with hooc or separate head coverin	Shoe Covers, and two pair of latex or nitrile gloves.

VISUAL AID

Step	Task Description	Manual Time	Automation Time	Transfer Time
1	RCT Swipes for radiation	10		
2	Crane Op. remove Top Lid	5		7
3	Prepare Blast Shield to be removed	7		
4	Remove Blast Shield			9
5	Remove Hardware/ convolutes, Clean area	23		
6	Remove 2 sections of MITLs	15		6
7	Remove 3 sections of MITLs	15		8
8	Clean/ Wipe center section	110		
9	Refurb/ Clean MITLs	105		
10	Fly Convolutes out			5
11	Fly Convolutes in			5
12	Install 3 Sections MITLs	15		5
13	Install 2 Sections MITLs	15		6
14	Install Convolutes	29		
15	Install Hardware	21		
16	Install Target	17		
17	Install Blast Shield	4		5
18	Clean Area/ Install O ring	8		
19	Install Top Lid	5		5

Standard Work Combination Chart (minutes)



Total: 404 (Takt Time) + 61 = 465 (Total Time); 404 - 465 = 61 (Waiting Time)

Manual ——— Automatic .... Walking Op. Waiting

Hazard Identification and Controls

Beryllium

The Center Section is a Beryllium Operational Activity Area (BOAA). It is controlled via PPE, the Center Section access list, the ADM_CBDPPIP_ADPRO, and IH support.

Gravity Hazards

Crane usage and suspended loads are controlled via the crane qualification card, direct supervision, and load support/resting devices. Swivel-hoist rings shall be used for the hoisting of components to and from the chamber.

Confined Space Entry

The Center Section is classified as a permit-required space but may be entered under C5 alternate procedures with continuous ventilation and atmospheric monitoring. Completion of SNL form SF 2001-CSA is mandatory for C5 entry. All entrants must be current in confined space safety and instrumentation training (CNF104).

Explosives

Explosives are used to close the UCV. Follow the direction of the Explosives Handlers. Operations personnel will not engage in direct handling of explosives. Explosives Handlers will maintain positive control of detonating devices. The "Dept. 1679 Lightning Warning & Protection Plan," ADM_LWP_APDRO, shall be followed when using explosives.

Chemical Use and Hazardous Waste Generation

Ethanol is used for cleaning vacuum surfaces. Safety glasses with side shields shall be used when dispensing ethanol. Do not introduce any more ethanol in the Center Section than is necessary to accomplish the work. Eliminate/prohibit all ignition sources in the work zone. Wet or damp ethanol wipes shall be managed and disposed of as beryllium contaminated.

Stage 1, Conclusions

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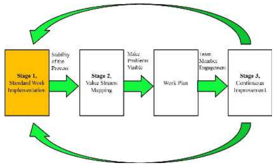

- Standardization is an essential piece to the implementation of lean tools in any environment. As it was explained in this Stage, the work done at the Z facility is performed by well trained and experienced personnel, that have been working on the machine for several years. The personnel do not follow any standards, in terms of process workflow. They do have standards and procedures regarding the specifications of the machine, but not for the time required to perform each task.
- Stage 1 represents how the standardized work can be used to create predictability while enabling innovation, achieve integration and coordination of the workers, support problem solving by making the process **Stable**, and enable organizational learning. This supports the effective execution of work in complex environments such as research and development laboratories.

Stage 2, Identify Non-Value-Added Activities

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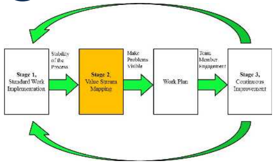


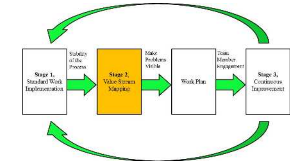
- In Stage 2, the mid-term focus is on improving the efficiency of the value stream. Once tasks at the Z process are stable and standardized, the value stream can be improved by analyzing the critical path of the process and sorting out non value-added from value-added activities based on customers' perspective.
- The efficiency of the value stream will be improved through recognizing the problems and creating an action plan to solve them.
- Value Stream Map, is a Lean tool specified into sort out value-added from non value added activities. This tool is used to make problems **Visible**, enable people to **Solve** them, and **Capture** what is learned throughout the organization.
- Current State Map (CSM) is a graphic depiction of what is currently happening on the floor, and it allows everyone to see and agree what is occurring.

Data Collection

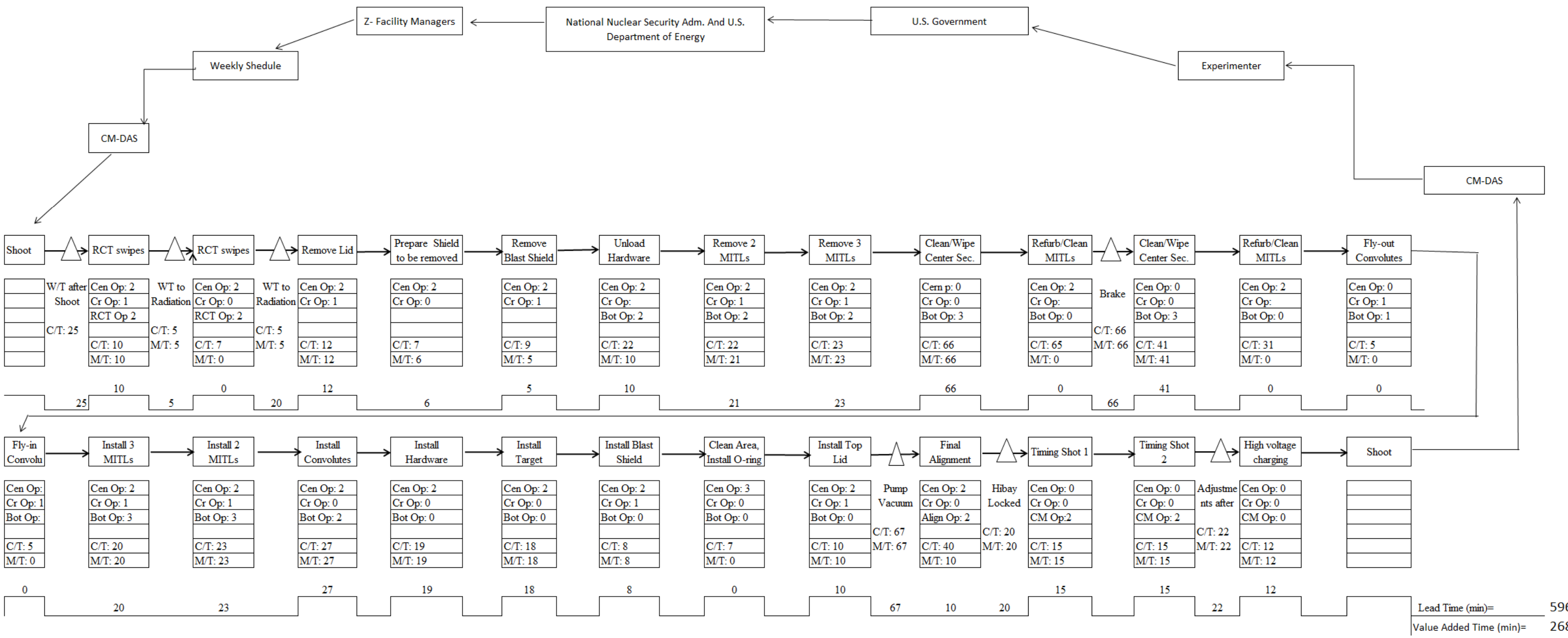
- Despite the fact that every experiment at Z is different, we must also recognize that the time spent at almost every task is very repeatable: even though the machine configuration and diagnostics need changes every day, the amount of time spent does not vary significantly. .

Critical Path	Z2366	Z2367	Z2368	Z2369	Z2382	Z2383	Z2384	Z2385	Z2386	Z2387	Z2390	Z2396	Z2399	Z2403	Z2404	Z2405	Z2406	Z2408	Z2409	Z2411	Max	Min	Average
Shot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Access granted to Hibay (Charge and Dump)	25	25	25	24	25	23	25	30	16 *	27	22	28	25	25	20	30	30	25	20	20	30	20	**25**
RCT Swipes for radiation	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	**10**
RCT Swipes again	5	5	5	5	10	10	10	5	5	5	5	5	5	5	5	5	10	5	10	10	10	5	**7**
Crane Op. remove Top Lid	10	15	10	10	10	10	10	10	15	15	10	10	10	15	10	10	15	15	15	10	15	10	**12**
Prepare Blast Shield to be removed	13 *	5	8	10	5	5	5	5	10	5	5	5	5	5	5	10	5	5	5	8	10	5	**6**
Remove Blast Shield	5	7	10	14	12	10	15	5	5	5	10	10	5	10	10	12	10	10	10	5	15	5	**9**
Remove Hardware/ convolutes, Clean area	20	18	22	25	15	20	20	30	30	25	25	20	20	30	25	15	20	20	22	25	30	15	**22**
Remove 2 sections of MITLs	20	25	25	20	20	22	25	10	25	20	20	20	20	25	20	20	25	20	20	20	25	10	**21**
Remove 3 sections of MITLs	20	27	20	25	25	25	25	17	20	25	25	25	22	20	25	25	22	25	25	25	27	17	**23**
Clean/ Wipe center section	55	65	65	70	70	75	65	75	75	60	65	65	70	60	60	55	60	70	65	70	75	55	**66**
Refurb/ Clean MITLs	65	70	65	70	80	70	65	48 *	65	65	60	70	70	60	60	65	70	55	65	65	80	55	**66**
Break	75	60	65	65	80	60	60	70	65	75	65	70	75	60	60	65	60	70	60	60	80	60	**66**
Clean/ Wipe center section (Con't)	40	50	35	40	40	45	50	35	40	40	35	40	45	40	40	35	45	40	40	35	50	35	**41**
Refurb/ Clean MITLs (Con't)	30	40 *	30	35	35	30	35	25	35	25	35	30	25	30	35	25	25	30	30	30	35	25	**30**
Fly Convolutes out	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	**5**
Fly Convolutes in	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	**5**
Install 3 Sections MITLs	20	20	20	20	18	21	25	13 *	20	20	20	20	25	25	20	15	20	15	15	22	25	15	**20**
Install 2 Sections MITLs	25	25	20	25	15	25	30	22	20	25	22	28	20	25	20	20	20	25	30	25	30	15	**23**
Install Convolutes	30	25	30	25	25	30	35	25	32	25	30	25	20	30	30	22	22	24	28	20	35	20	**27**
Install Hardware	15	20	25	22	18	25	25	15	25	15	20	15	15	20	15	20	18	16	20	15	25	15	**19**
Install Target	15	15	15	20	25	20	20	8 *	20	10	20	20	15	15	15	15	20	25	20	20	25	10	**18**
Install Blast Shield	15	15	10	10	10	5	5	5	5	10	5	10	15	5	5	10	5	10	5	5	15	5	**8**
Clean Area/ Install O-ring	5	10	10	10	10	10	5	5	5	5	10	10	10	5	5	5	5	5	5	5	10	5	**7**
Install Top Lid	10	10	10	10	10	10	10	7 *	10	10	10	10	10	10	10	10	10	10	10	10	10	10	**10**
Pump Vacuum	60	60	70	60	60	70	80 *	65	65	75	60	75	65	65	65	60	70	65	75	75	75	60	**66**
High Bay Locked up	20	20	20	25	10	15	20	20	20	16	20	20	20	20	20	25	20	20	20	15	25	10	**19**
Timing Shoot 1	10	16	10	10	10	10	12	10	25	10	10	10	10	20	15	15	10	15	10	10	25	10	**12**
Timing Shoot 2	10	19	10	18	10	15	14	10	20	15	10	10	10	20	20	10	15	15	25	20	25	10	**15**
High Voltage Charging	15	10	10	10	20	15	40 *	5	5	15	5	15	10	10	15	10	10	5	10	10	20	5	**11**

Stage 2, VSM Current State



- The sequence described in the VSM is considering only those tasks that affect the process time (Critical Path). The total lead time of the process is **596** minutes, and the value added time of the process is only **268** minutes on average.



Stage 2, Identify Non-Value-Added Activities

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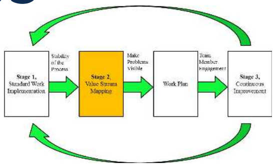

- We identify **Seven** Non- Value-Added activities from the CSM

Non Value-Added Activities Description	Department that Perform the Task	Time Spent
Break before the MITLs are installed back to the machine after being refurbished	Center Section	66 minutes
Time required to remove MITLs out of the machine	Center Section	45 minutes (performed in two steps)
Time required to install back MITLs to the machine	Center Section	45 minutes (performed in two steps)
Time required to achieve vacuum level required.	Vacuum Section	67 minutes
Time required for realignment of diagnostics before timing shots	Diagnostics Section	10 minutes
Time required to perform the high bay lock up	ESS-PFS and CM-DAS Sections	20 minutes
Time required for final alignment of diagnostics after timing shots	Diagnostics Section	22 minutes

Stage 2, Conclusions

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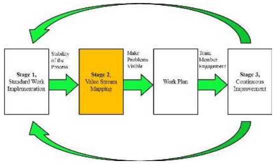
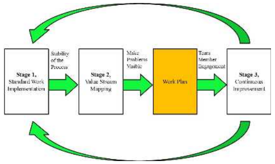


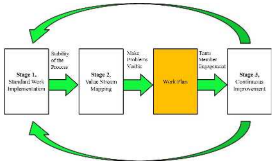
- The **66 minutes** of break time taken between MITL refurbishment and MITL install is something that we suggest to just eliminate as this is an additional break to the lunch break.
- Regarding the **45 minutes** spent to remove/ install back the MITLs are definitely needed. Every MITL weighs over 3 tons, and the current MITL flipper is not designed to handle this much weight at the same time.
- After analyzing the Vacuum Section deeper and looking for alternatives to reduce the time needed to perform vacuum pumpdown (**67 minutes**) we determined that this timing is constrained by the performance of the equipment itself (vacuum pumps).
- Regarding the **20 minutes** to perform the high bay lock up: this time is used by ESS-PFS sections to ensure there is no one inside of the high bay for the incoming shot. If after these 20 minutes of inspection over the proper alignments of the diagnostics, they realize that there is an issue, then the diagnosticians will need to make final alignments, which are represented as the **22 minutes** for final adjustments. These 42 minutes can be reduced or eliminated if we ensure that every section and diagnostics are ready and aligned to perform the first timing shot.

Work Plan



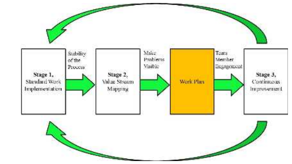
- Following the findings from Stage 2, in which we separated the non-value-added activities **NOT** needed from the necessarily non-value-added activities in the system, we identify a total of **113 minutes** classified as not needed in the system or activities that if we reduced or eliminated them from our system, there would be no adverse effects.
  - We are proposing to move the break time (66 min) to either forward or backward this to avoid having it fall into the critical path of the Z process.
  - We suggest to implement a checklist or even a TPM to make sure that every day all of the diagnostics are inspected and working properly even if they are not going to be needed that day. If we ensure the appropriate alignment and connection of every diagnostic needed for the current experiment, we can reduce or even eliminate 47 minutes out of the critical path (10 min of alignments before lock up + 22 min of alignments after lock up + reduce to 5 min lock up time).

Work Plan

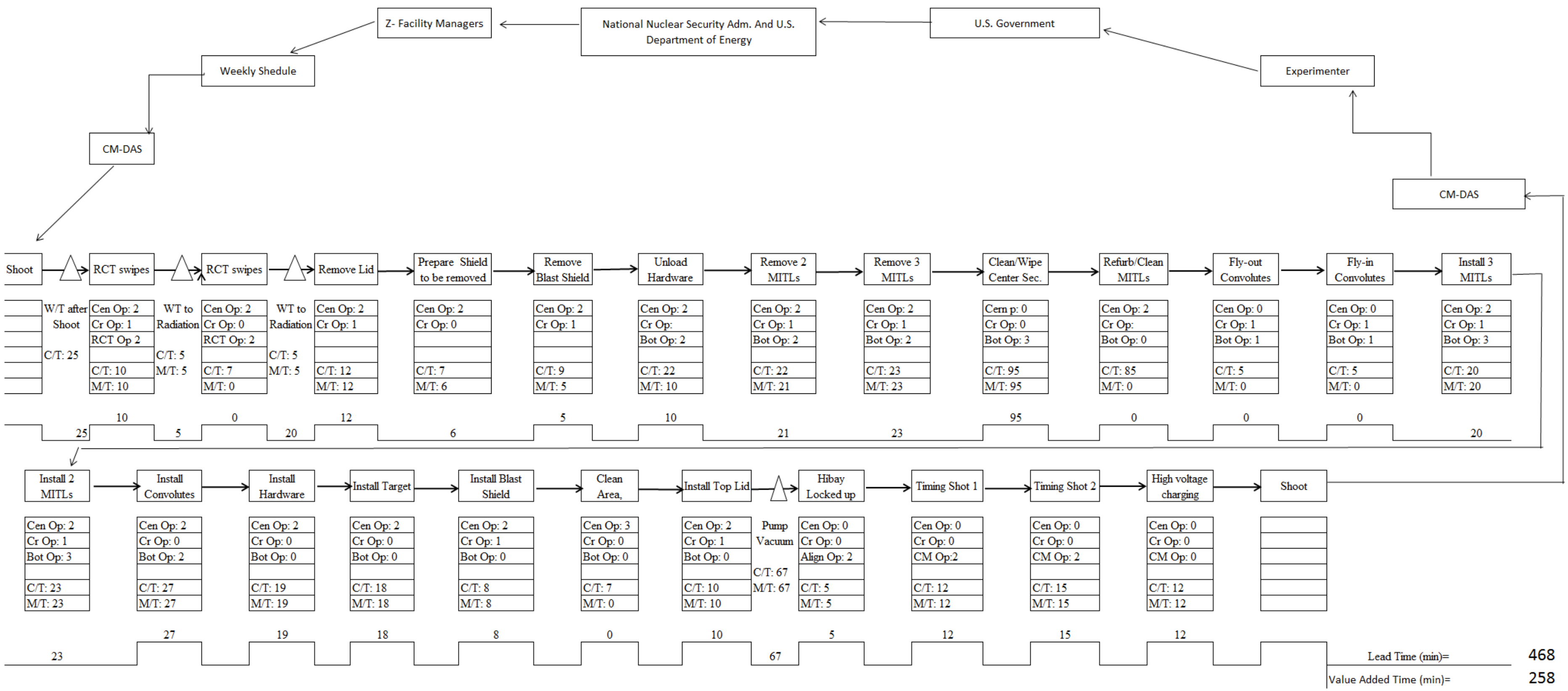


Non Value-Added Activities Description	Department that Perform the Task	Time Spent	Time Suggested to be Spent
Break before the MITLs are installed back to the machine after being refurbished	Center Section	66 minutes	Eliminated, 0 minutes
Time required to remove MITLs out of the machine	Center Section	45 minutes (performed in two steps)	Remain the same, 45 minutes
Time required to install back MITLs to the machine	Center Section	45 minutes (performed in two steps)	Remain the same, 45 minutes
Time required to achieve vacuum level required.	Vacuum Section	67 minutes	Remain the same, 67 minutes
Time required for realignment of diagnostics before timing shots	Diagnostics Section	10 minutes	Eliminated, 0 minutes
Time required to perform the high bay lock up	ESS-PFS and CM-DAS Sections	20 minutes	Reduced to 5 minutes
Time required for final alignment of diagnostics after timing shots	Diagnostics Section	22 minutes	Eliminated, 0 minutes

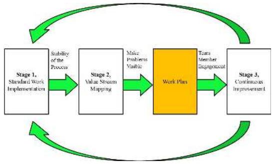
Suggested Future State



- The Future State Map eliminated the 66 minute break and the 47 minutes of an alignment after the vacuum condition is achieved.



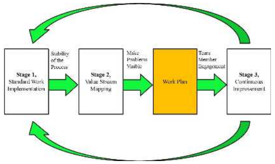
Proposed Improvement Plan



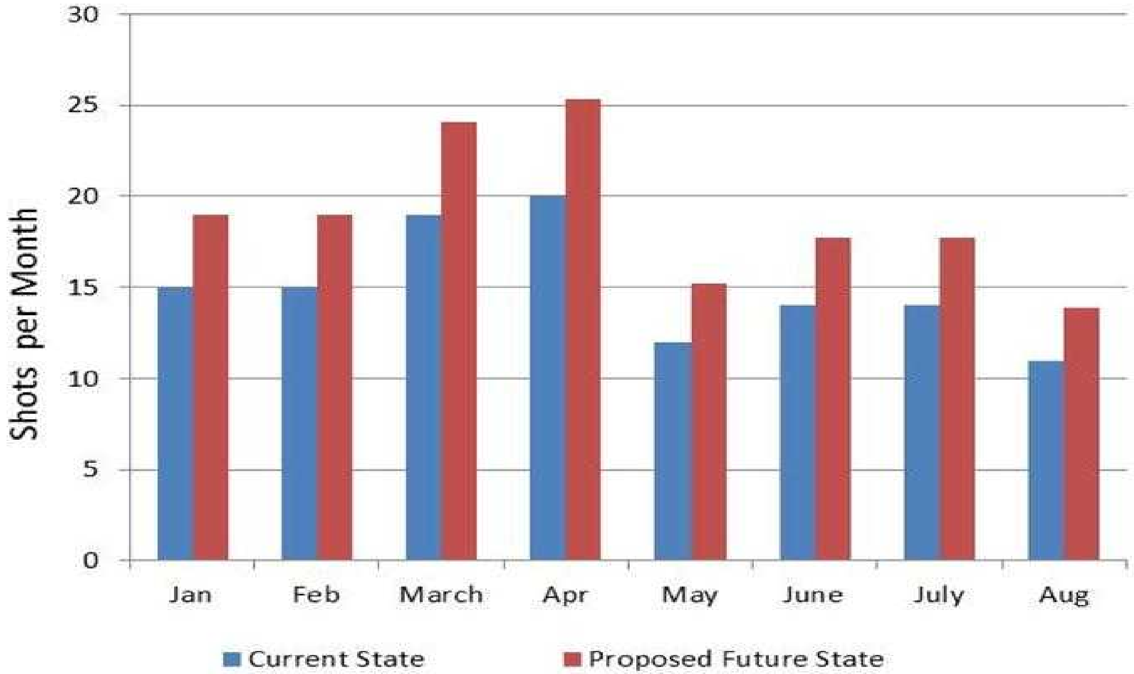
- By achieving the modifications previously suggested, the total lead time of the process will have a theoretical improvement of 26% .

Year 2012	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Experiments
Current State	15	15	19	20	12	14	14	11	**120**
Proposed Future State	19	19	24	25	15	18	18	14	**152**
Hrs. Worked on the machine per month	148	148	187	197	118	138	138	109	**26%**

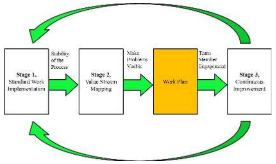
Proposed Improvement Plan



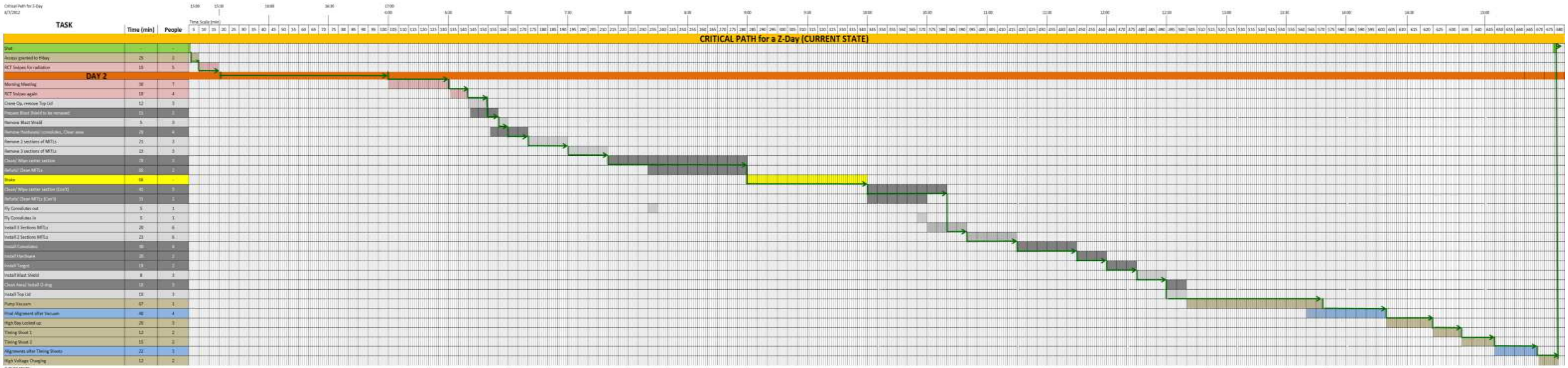
- As we can see from this graph, if we modify the process following our suggestions described in this research and with the same amount of time available per month, they can increase the number of experiments for over 25%.
- This would be the first improvement moving toward Lean Six Sigma implementation at the Z facility.

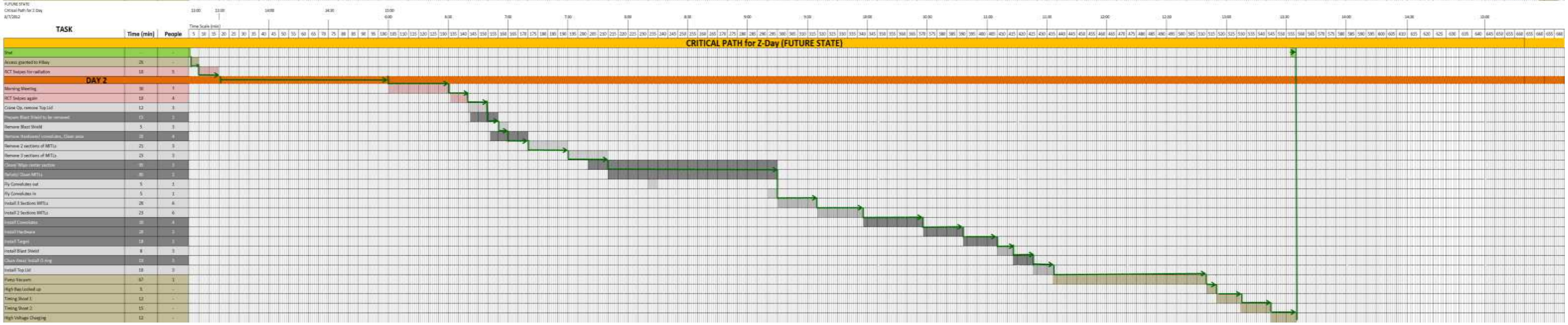


CSM vs. FSM



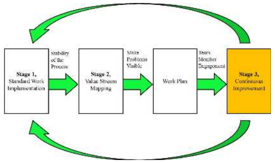
- This Table describes a visual comparison of the improvements if we move from the current state (upper table) to future state proposed (lower table).





Stage 3, Continuous Improvement

Sandia National Laboratories



- The long-term analysis in Stage 3 is to progress in both dimensions by continuously improving standard work procedures and the flow of value stream. Value Steam Mapping and visual management are used to recognize problems, so that they can be solved. Standardization is used as the foundation of continuous improvement and to support organization learning.
- This final Stage, suggest that once we have reach the Future State established with the work plan, keep looking for continuous improvements through the value stream. Either improving current standardized work sheets or proposing innovative ideas to perform different tasks at the facility, keeping in mind the final **Goal**: to produce at the lowest cost with the highest quality while eliminating any sort of waste in the value stream and to always keep looking for continuous improvements within the system.

Concluding Remarks

- The intent of this research was to understand the challenges, and approaches that resulted in effective practice of lean principles
- Stage 1, describes the steps suggested for implementation before we attempt to implement lean tools to improve the value stream of the operation, such as standardization of the system and an in-depth process description of every department at the Z facility.
- Stage 2, is a detailed case study of how Value Stream Mapping plays a role in the introduction of lean principles while achieving cross-functional integration. These tools were used in a manner that engaged team members while enabling them to develop and modify tools to best support their work.
- Lastly, Stage 3 refers to long-term lean tools implementation to progress in both dimensions, to improve the effectiveness of the operations and the efficiency of the value stream. By continuously improved standard work procedures and the efficiency of the flow of the system.

Contribution of this Research

- This research provides a framework for research and development laboratories, similar to the Z facility at Sandia National Laboratories, interested in applying Lean Six Sigma methodology in their processes.
- This case study presents a Three-Stages approach for Lean Six Sigma implementation.
  - Emphasize the needs of having a standardized process, were its main purpose is to **Stabilize** the process.
  - Followed by the implementation of analytical Lean Six Sigma tools, such as Value Stream Mapping. To **Separate** value-added activities from non value-added activities, and to sort out any type of wastes in the process.
  - Lastly, stresses the common goal of Lean Six Sigma methodology, which is to **Continuously Improve** the value stream.

Future Research

- Future research should look at the role of standardization to enable the stability of the process at any R&D laboratory. Furthermore, to explore in-depth for the more suited lean tools to problem solving and root cause analysis, to be utilized at any R&D laboratories environment.
- Specific future research for the Z facility includes:
  - Investigate the unexpected delays deeper, using root cause analysis, especially those events that happen at higher frequencies, and to identify if those events were caused due to a maintenance issue, operational errors, or other traceable issues.
  - Validate the effectiveness of the standardized worksheets proposed, in terms of stability of the process.
  - Explore the possibility to changing to two work shifts; a full analysis should be made in order to show the pros and cons of this modification in terms of process time reduction versus labor cost.

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