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Requirements Doc for Refurb of JASPER Facility in B131HB

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Requirements Document for the Refurbishment of the JASPER Facility in the B131 High Bay

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by Kenn Knittel
20 January 2017

1. EXECUTIVE SUMMARY

The Joint Actinide Shock Physics Experimental Research (JASPER) Program target fabrication facility is currently located in building 131 (B131) of the Lawrence Livermore National Laboratory (LLNL). A portion of this current facility has been committed to another program as part of a larger effort to consolidate LLNL capabilities into newer facilities. This facility assembles precision targets for scientific studies at the Nevada National Security Site (NNSS). B131 is also going through a modernization project to upgrade the infrastructure and abate asbestos. These activities will interrupt the continuous target fabrication efforts for the JASPER Program.

Several options are explored to meet the above conflicting requirements, with the final recommendation to prepare a new facility for JASPER target fabrication operations before modernization efforts begin in the current facility assigned to JASPER. This recommendation fits within all schedule constraints and minimizes the disruption to the JASPER Program. This option is not without risk, as it requires moving an aged, precision coordinate measuring machine, which is essential to the JASPER Program's success. The selected option balances the risk to the machine with continuity of operations.

2. MISSION DESCRIPTION

The Lawrence Livermore National Laboratory (LLNL) is undertaking numerous multimillion dollar facility renovation and new construction projects. The current Joint Actinide Shock Physics Experimental Research (JASPER) Program target fabrication facility in building 131 (B131) is at the early nexus of these plans. This facility precision assembles targets for scientific studies at the Nevada National Security Site (NNSS).

Figure 1: The Jasper two-stage gas gun at the Nevada National Security Site, as seen from the loading port. The target chamber is visible in the background.

JASPER occupies two rooms in B131, both of which need to be renovated as part of a multi-year effort to refurbish the B131 High Bay assembly facility to bring it from 1960s to 21st century standards. The B131 refurbishment effort is led by the Defense Technology Engineering Division (DTED) for LLNL, the current programmatic occupants of the B131 High Bay. One of the rooms currently occupied by JASPER has also been designated to be used by the Advanced Composites Engineering (ACE) Facility, in addition to another adjacent room, when that facility moves from its current location as part of a capability reorganization effort that will move several capabilities out of another building that is beyond its service lifetime and no longer meets numerous current civil codes.

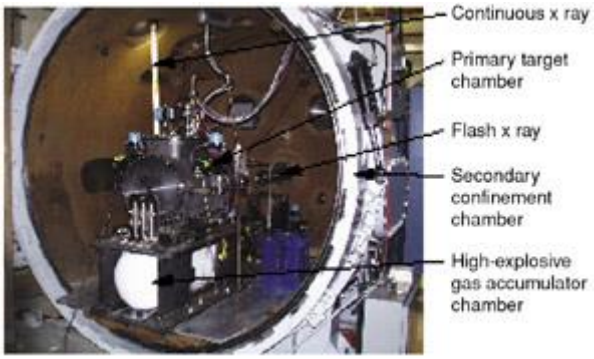

Figure 2: Secondary confinement chamber and internal arrangements

The net effect on the JASPER Program is that it will not be able to conduct work in its current location for several months during the refurbishment, and when the ACE Facility relocation is complete the JASPER Program will have less space available and will share one of its rooms with an additional program.

Given that ***DTED needs to refurbish the two rooms currently occupied by the JASPER Program in the B131 High Bay***, this paper will document requirements for the JASPER Program and propose the future location and composition of their target assembly area.

Mission

DTED needs to refurbish the two rooms currently occupied by the JASPER Program in the B131 High Bay.

Goals

JASPER experiments provide scientific data on the material properties of various materials essential to national security applications. The program is a fundamental component of the stockpile stewardship program, with experiments planned for the next several years. Therefore, the planned JASPER experimental program must continue to be supported without significant interruption, and the quality of the current target assemblies must be maintained. This should be achieved within the context of moving the ACE Facility and refurbishing the B131 High Bay.

Objectives

To meet these goals, DTED must:

- Refurbish rooms 1450, 1450C and 1460 in B131
- Move the ACE Facility into rooms 1450C and 1460 in B131
- Allow continuation of the experimental program at the JASPER Facility in Nevada throughout the refurbishment project, which may include:
    - Building more targets before refurbishment activities commence, or
    - Rearranging the target assembly plans to assemble different targets in another location during the refurbishment activities

Operational Constraints

The following constraints have been imposed by higher authorities:

- The ACE Facility must be installed in B131
- The ACE Facility must be commissioned during FY17
- The current essential functional capabilities of the JASPER target fabrication facility must be retained at the end of this refurbishment project
- The current quality standards for JASPER target assemblies must be retained at the end of this refurbishment project
- The JASPER target fabrication facility must retain the Moore precision coordinate measuring machine (CMM)
- The current capacity to assemble targets for JASPER must be retained at the end of this refurbishment project

Retaining the Moore CMM is the most complicated constraint in this project. The machine is over 30 years old and is no longer supported by the manufacturer. When the machine "crashes," the JASPER Program brings a technician out of retirement to repair it. Since it was originally designed to measurement objects to sub-micron accuracy, it has very fine motor controls. It is currently used by the JASPER Program to position components during assembly at several orders of magnitude greater than the precision it was designed for. The machine is being underutilized. However, since it is the machine that has always been used, it has proven the target assembly process to be successful and is the "machine of record." It could be replaced with a new machine that meets the accuracy requirements, but the experimentalist are loathe to change their process. Attempts to replace it in the past have met with significant resistance. Any failure of the Moore is a significant risk to the JASPER Program, but one they are willing to accept. The decision to retain the Moore machine is an emotional one, not a logical one.

Stakeholders

Stakeholders for the JASPER target assemblies and the B131 facility are identified in Figure 3. Stakeholders were divided into Active Stakeholders (those that directly interact with the JASPER target assembly or influence the quality of the build) and Passive Stakeholders (those that influence the assembly process or specify the acceptance of the target or the data it produces). These stakeholders include members of the JASPER experimental team, the technicians and engineers directly involved in the assembly of the targets, members of the facility staff, programmatic leadership, and various LLNL institutional process and control organizations.

Individual stakeholders were interviewed and asked the following questions, and their responses are recorded in attachments A through G:

- Describe the work performed by the JASPER team in the B131HB.
- What capabilities of the current work area are essential to the JASPER project?
- What does the ideal work space look like?
- What capabilities does JASPER need that it currently doesn't have?
- What does JASPER's project schedule look like over the next year?
- When is the JASPER work load lightest or most critical?

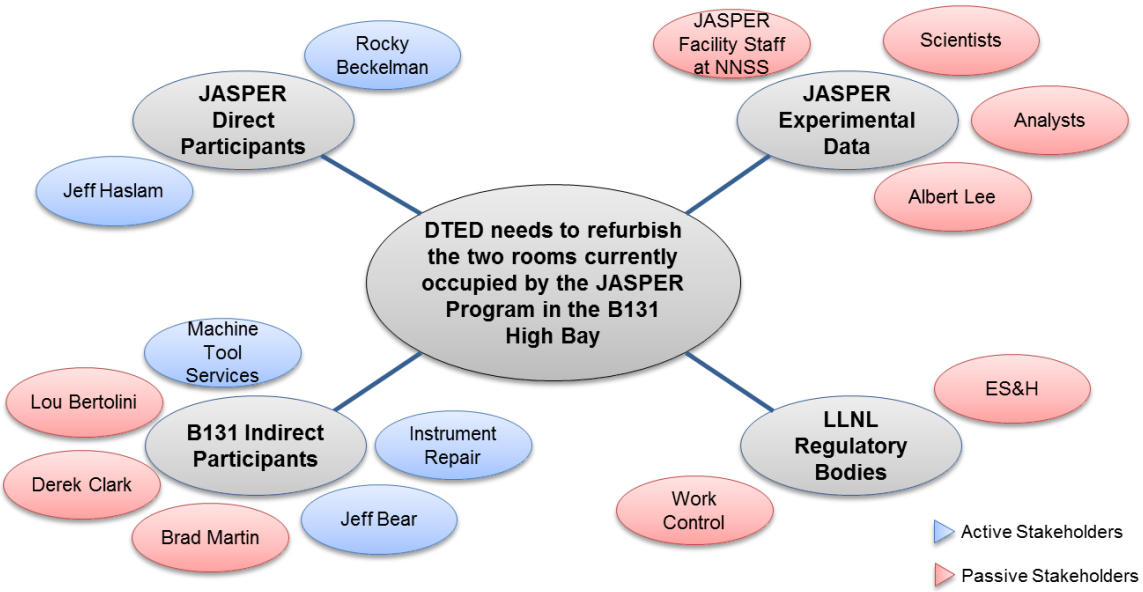

Figure 3: JASPER and B131 Stakeholders

Active Stakeholders

- Rocky Beckelman – JASPER Lead Technician (Attachment A)
- Jeff Haslam – JASPER Lead Engineer (Attachment B)

Passive Stakeholders

- Jeff Baer – LLNL Lead HVAC Maintenance Technician (Attachment C)
- Lou Bertolini – DTED Associate Division Leader (Attachment D)
- Derek Clark – B131 High Bay Facility Work Coordinator (Attachment E)
- Albert Lee – JASPER Program Manager (Attachment F)
- Brad Martin – B131 High Bay Manager, Technician Supervisor (Attachment G)

Acceptance Criteria

Upon completion of the stakeholder interviews, the criteria in the following table were identified for the continued success of the JASPER Program target fabrication area, some of which must also be met during the upcoming facility refurbishment. The criteria have been divided into functional capabilities and their associated characteristics (properties or attributes). Each capability or characteristic is traced back to at least one stakeholder interview (see Section 8, System Requirements).

Table 1: Capabilities and Characteristics of a successful JASPER target assembly area.

Capability	Characteristic
Uninterrupted assembly operations	Delays more than a few days are unacceptable
Scheduling flexibility	
Temperature/humidity controls for assembly room	Stable temperature (+/- 1°C) Humidity <15% Reliable HVAC equipment

Capability	Characteristic
Cleanliness controls for assembly room	Less than size of dust particle
Coordinate measuring machine	Moore machine is required <25um accuracy
Overhead crane	Lifting 500lb loads Not in the way when not in use Slow operational speed with no overrun
Large, flexible assembly space	Several workbenches for assembly, testing and validating Open floor space for staging Space to expand for future operations/capabilities Access to machines/instruments for maintenance
Adequate storage capacity	All current cabinets are used Include floor space for pallets
Adequate lighting	(Needs further refinement)
Comfortable noise levels	(Needs further refinement)
Controlled access to assembly room	
Access to machine shop	

Sacred Expectations

The above criteria were analyzed for their impact on the JASPER target assembly process and subsequent impacts to the experimental program. Data from JASPER experiments is used by the Stockpile Stewardship Program to assure the continued reliability of our national deterrence weapons. This mission is of the highest importance, so target assembly and testing must continue at a reasonable pace. Simple targets can be fabricated elsewhere on the LLNL site, but the complex targets can only be assembled on the Moore precision CMM. Though the JASPER experimental program may experience schedule changes, the JASPER Facility at the NNSS is unique in its capabilities and the facility should not sit idle for lack of targets.

The sole purpose for the JASPER Facility at the NNSS is to determine the properties of various materials under extreme pressures, so anything that would compromise the properties of the test specimen or the accuracy of the data is unacceptable. Though temperature excursions within the assembly area can be mitigated by waiting for thermal equilibrium to return in a few days, humidity excursions can permanently alter the test specimens.

Accurately assembling the test samples into target assemblies is also vital to the integrity of the experimental data. Many machines and instruments are used for this purpose. The JASPER target fabrication facility in B131 currently has all the equipment necessary to assemble targets to the level of precision needed to produce repeatable and accurate experimental data. There are no excess capabilities in the current facility; though the Moore CMM is known to be aged, it is irreplaceable. The facility currently does not have any cleanliness controls beyond routine housekeeping, but cleanliness is known to adversely impact the target assembly duration.

The acceptance criteria are thus distilled to the following key performance parameters:

- Experimental Program – experimental operations cannot be delayed, thus a steady supply of targets is paramount
- Data Quality – the materials tested must remain in a low humidity environment

- Data Quality – the current assembly, testing and validating capabilities must be retained
- Operations – adequate space must be provided to organize the assembly area for efficient operations and maintenance

3. SYSTEM OPERATIONAL CONTEXT and REFERENCE OPERATIONAL ARCHITECTURE

Though every target for JASPER is a custom assembly to test various attributes of the subject material, the interfaces for the JASPER target fabrication facility in B131 are consistent and straight forward. First, target designs and the necessary materials are delivered to the facility. Then the target assembly and validation processes are iterated until the requirements of the specific target can met. Finally, the target is assembled into the primary target chamber (PTC) and shipped to the NNSS. All of this is performed with oversight from various programmatic and institutional organizations as shown in the figure below.

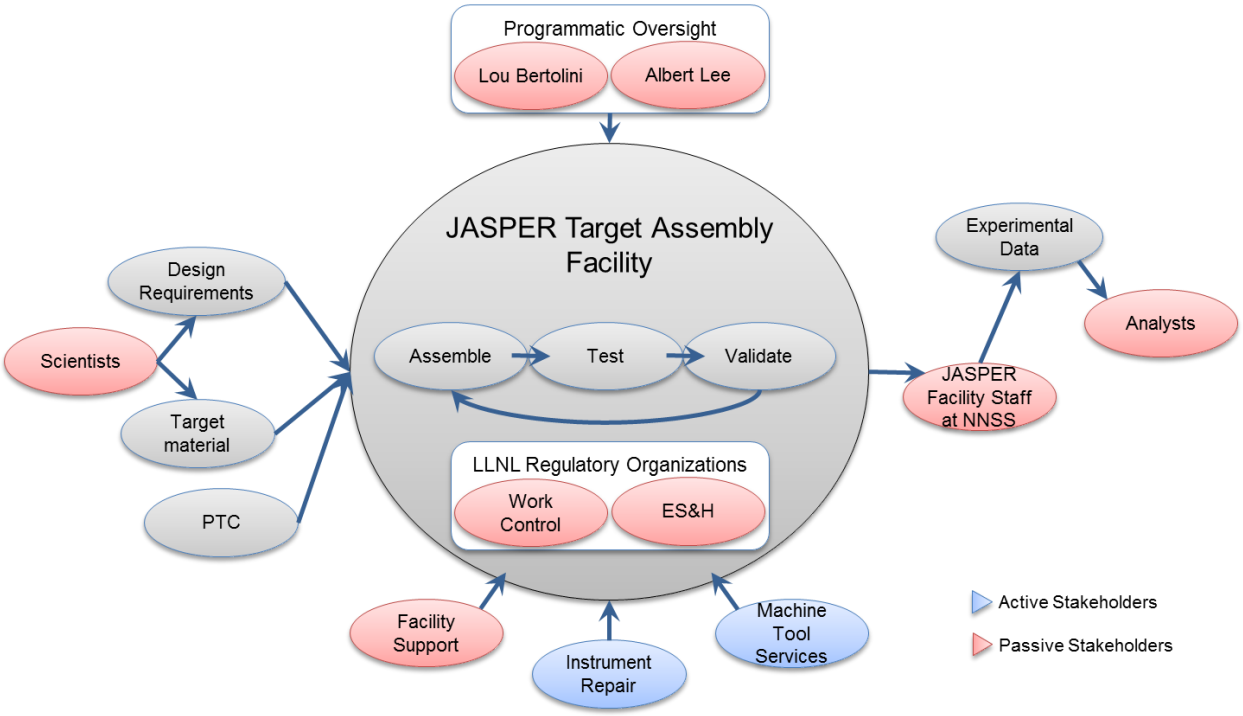

Figure 4: JASPER target fabrication facility context diagram

The JASPER target fabrication facility currently occupies two rooms in B131. This mechanical assembly area has evolved over the years as more or less space has been made available. The lead technician has maintained a reasonably organized work area with all equipment and storage cabinets collocated for each capability. The current JASPER target fabrication facility floor plan is shown in Figure 5.

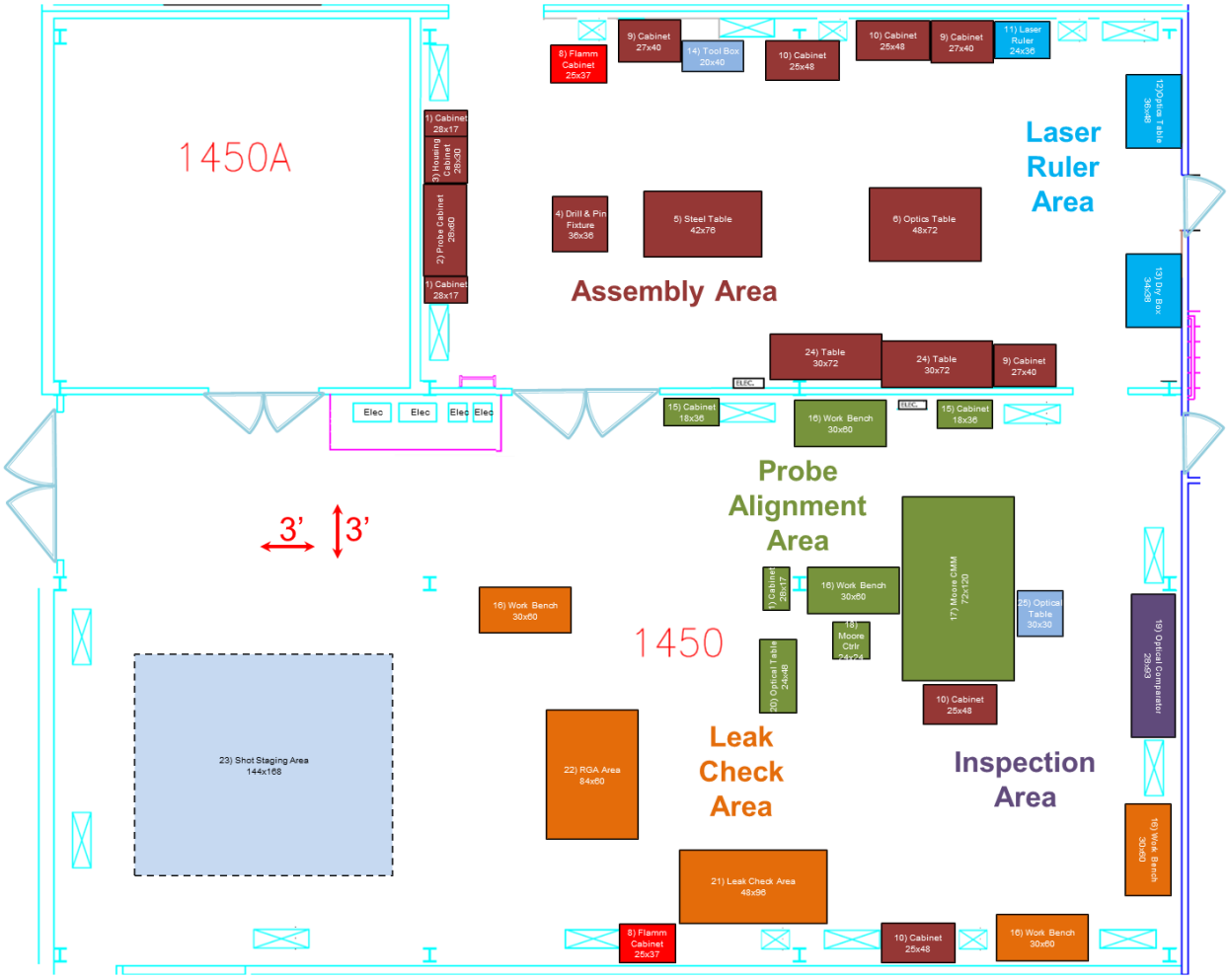

Figure 5: Current JASPER target fabrication facility layout in B131 rooms 1450 and 1450C

4. OPERATIONAL SCENARIOS

Every JASPER target is unique and is designed to measure a specific regime of the material properties of the sample being tested. It follows that every target is assembled following a unique procedure, but the generic overall process for every target is summarized in the figure on the next page. The target assemblies move from the central assembly area to the various other areas as needed, then back to the assembly area. Assembly durations span from a few weeks to several months, depending on target complexity.

The color coding the of activities in Figure 6 match the color coding of the current (Figure 5) and proposed (Figure 10) layouts. The process flow diagram thus also roughly represents the functional architecture of the JASPER target assembly process where the colors represent the functional location of the work being performed and the text in the box describes

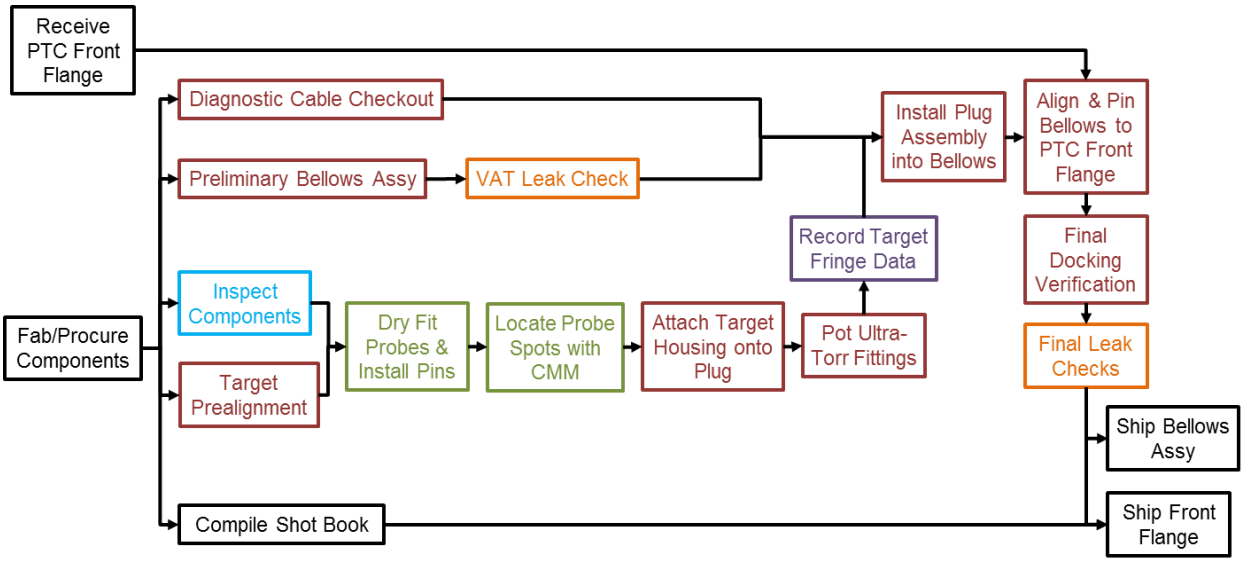

Figure 6: Generalized JASPER target assembly process flow diagram

the various activities performed in that location. For this project, the solution needs to preserve this process.

5. IMPLEMENTATION CONCEPTS SELECTED and RATIONALE

Four options are available to the JASPER Program during the B131 refurbishment project:

- Do not refurbish the rooms currently occupied by JASPER
- Move JASPER target assembly to a temporary location with limited functionality
- Move JASPER target assembly into a new permanent location
- Shutdown JASPER target assembly while the rooms are refurbished

These options were evaluated using the Pugh Matrix method with the sacred expectations as shown in Table 2. Each option was evaluated against the sacred expectations and scored for exceeding expectations (+), satisfying expectations (S) or not meeting expectations (-). For options involving risk to the target assemblies, where no clear determination can be made, a question mark (?) was assigned. These results were weighted with one, zero, negative one or zero points, respectively, and summed.

	Do Nothing	Temporary Location	New Permanent Location	Shutdown
Steady Target Supply	S	S	+	--
Low Humidity	S	?	S	S
Retain Current Capabilities	S	-	S	S
Adequate Space	-	-	S	-
+	0	0	1	0
S	3	1	3	3
-	-1	-2	0	-3
Sum	-1	-2	1	-3

Table 2: Pugh Matrix evaluating JASPER's options against sacred expectations

The first option defers the refurbishment of the rooms currently occupied by JASPER in B131 to an unspecified date. While this option satisfies most of the sacred expectations, it does not satisfy the charter requirement of the project to refurbish the High Bay and ultimately would result in JASPER's collocation with the ACE Facility. One of the rooms, and its crane, currently occupied by the JASPER target fabrication facility would be shared with the ACE Facility. This would reduce the amount of room available for JASPER and sharing resources could also have adverse effects. This option ultimately earns a score of -1.

The second option would require moving some limited capacity of the JASPER target fabrication facility to a temporary location during the room refurbishment, then returning it to its current location. While this would allow continued assembly of limited targets and keep the JASPER Facility at the NNSS operating, there are several issues with this approach in that the humidity controls of the new location may not be the same as the current location (introducing experimental uncertainty) and it is not clear that the Moore machine would survive two moves, so it would not be moved at all. This option earns a score of -2.

The third option outfits a new permanent location for the JASPER target fabrication facility. Ideally, this would be done before the current location is refurbished such that target assembly operations experience limited interruption during the move of their equipment. This new location would provide adequate space and facility equipment (cranes) to support all current capabilities. Several options were investigated to provide local humidity controls, but interestingly, another room (1431) was identified in B131 that is supplied from the same dehumidifier equipment so the humidity controls are the same. Moving and recommissioning the Moore machine is the biggest risk with this approach, though this would only be done once so the risk is somewhat controlled. This option earns a score of +1.

The final option, the extreme opposite of the first option, would involve shutting down the JASPER target assembly area for the remodel. No targets would be built during this time, and again the target fabrication facility would be collocated with the ACE Facility. This option earns a score of -3.

After reviewing all the options and grading them against the sacred expectations, the best option for further refinement is to prepare a new, permanent location the JASPER target fabrication facility.

6. USE CASES

Though individual targets can be rather complex, the sequence diagram and use cases for the JASPER target fabrication facility are relatively simple and uniform, as evidenced from the context diagram in Section 3 and the flow diagram in Section 4. The scientist determines which regions of a material's properties need to be evaluated and coordinates how the experiment can be successfully fielded at the test facility. The scientist and assembly technician then iterate the design requirements with assembly methods and tolerances to define the requirements and final acceptance criteria with the scientist. Following target acceptance, the assembly is shipped to the NNSS and receipt is acknowledged. The sequence and use case diagrams are shown below.

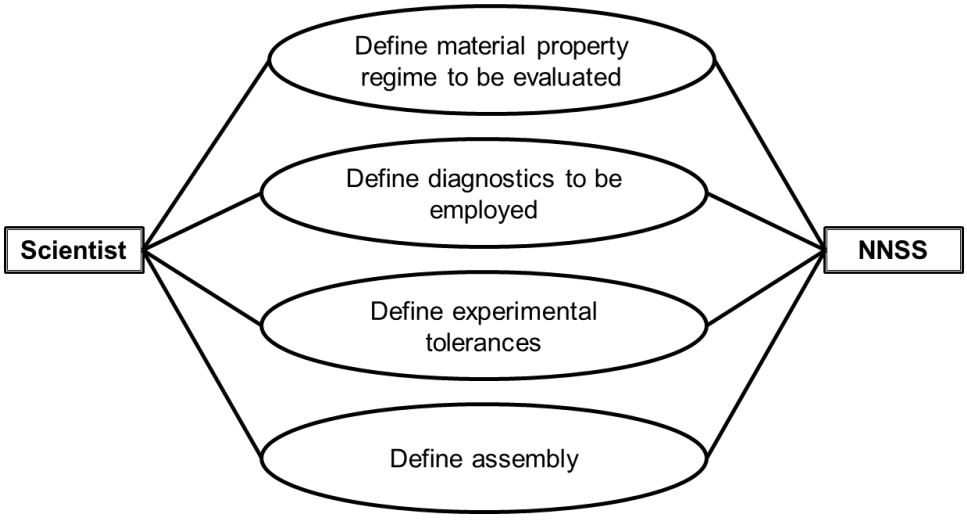

Figure 7: JASPER Targets Sequence Diagram

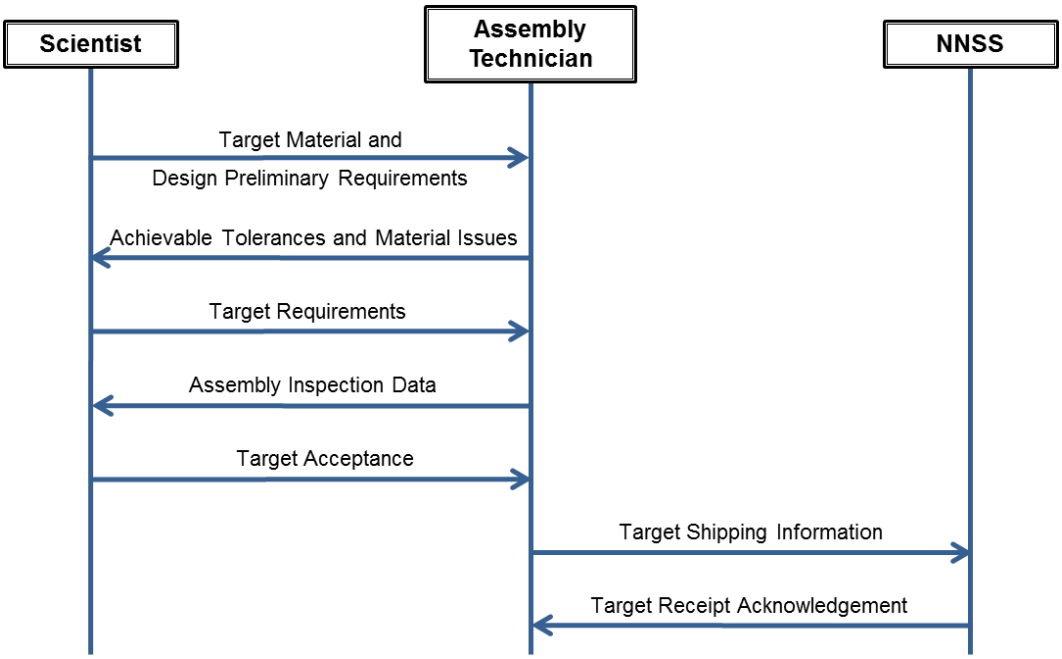

Figure 8: JASPER Target fabrication facility Use Case

Following interviews with the stakeholders and capturing the voice of the customer, a Quality Function Deployment (QFD) process was performed to further define the system level requirements and further evaluate the results of the Pugh Matrix. This process confirmed that

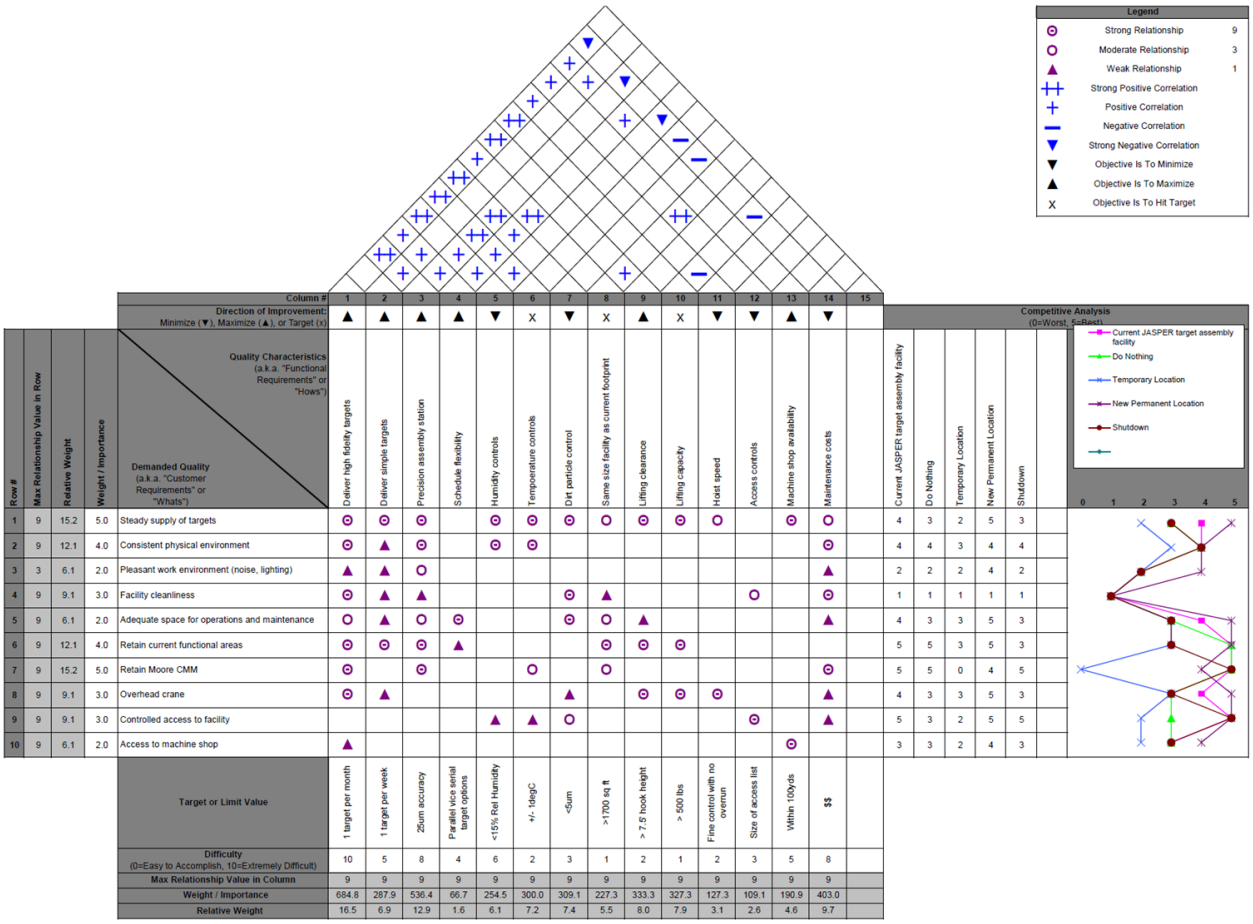

Figure 9: Quality Function Deployment for JASPER target fabrication facility

delivering a steady supply of high fidelity targets drives the other requirements for the facility. These two requirements currently drive all other capabilities and characteristics in the QFD, as seen in the first row, first column and left-most diagonal in the correlation peak. The facility is currently appropriately focused on its primary mission, and as seen from the competitive analysis of the options on the right side of the analysis results, this process confirmed the selection of the option to create a new permanent location for the JASPER target fabrication facility prior to the B131 High Bay refurbishment project.

From the QFD, the capabilities with the greatest impact (relationships and correlations) on the steady supply (Row 1) of high quality targets (Column 1) include precision assembly, appropriate environmental controls (temperature, humidity, cleanliness) and heavy lifting (crane). These capabilities also have the strongest impact on each other. In the QFD, the customer requirement for the Moore CMM (Row 7) was translated into a functional requirement for precision assembly and the ability to maintain this precision. As discussed previously, in this case the customer has specified the requirement and solution in the form of an existing machine. A new capability could be designed and fabricated in-house, or procured from a commercial

vendor, and a test target assembled to validate the new capability's suitability, but the JASPER Program has resisted efforts to do this, citing limited time and funding to justify their position.

When reviewing customer demands with the highest weighting and comparing the available options, the selected option to provide a new permanent location for the JASPER target fabrication facility is equivalent or superior to the other options, except for the risk involved in moving the Moore CMM. There is risk in disconnecting, moving and recommissioning the Moore CMM, but this risk is minimized by only moving it once. Not moving it at all (ultimately remaining in the current location) is not consistent with the other requirements. The possibility of moving it twice is highly undesirable and evidenced by the poor score for the temporary location option. This analysis is further refined in Section 11 and Attachment H.

At the top level of the current analysis, the QFD also showed that all customer requirements can be translated into functional requirements, and that all functional requirements are tied to customer demands. Notably, the requirements for adequate space for maintenance and operations need to be further evolved in the next QFD layer for each piece of equipment or capability area.

7. PROPOSED SYSTEM OPERATIONAL ARCHITECTURE

The proposed solution retains all the existing JASPER facility capabilities to assemble, test and validate targets within B131 room 1431. The proposed location will be refurbished before the JASPER equipment is moved, including the addition of a small (half ton) monorail crane. The room can be arranged to better collocate storage cabinets and promote the flow of the target assembly through the various stations.

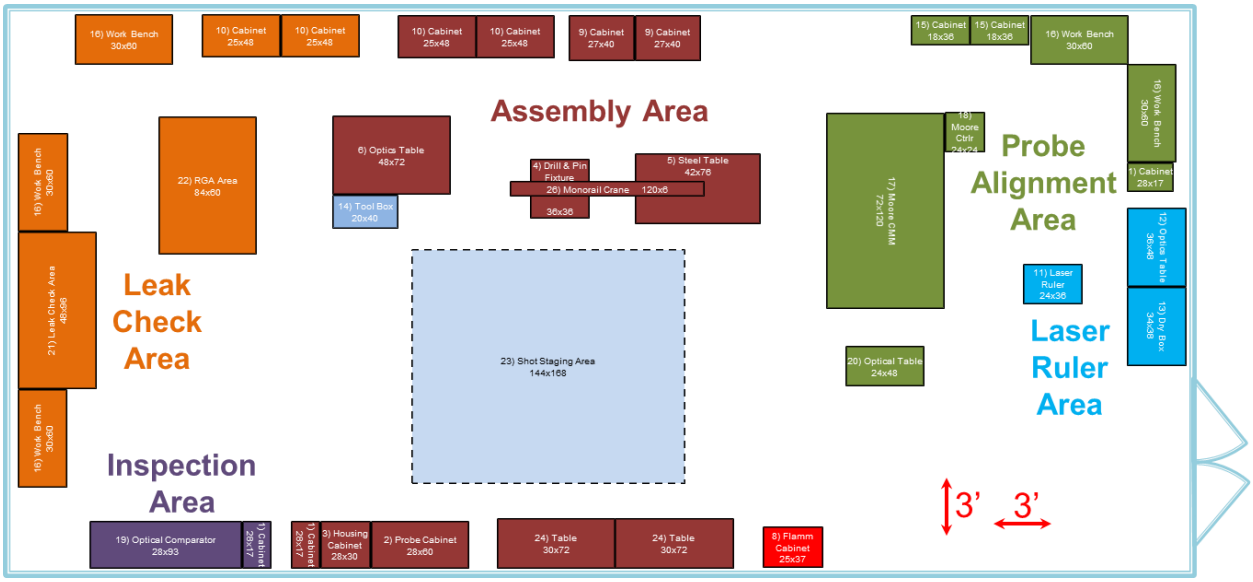

Figure 10: Proposed floorplan for JASPER target assmebly facility in B131 room 1431

8. SYSTEM REQUIREMENTS

The functional system requirements are derived from the voice of the customer as distilled from their required capabilities and characteristics. The QFD process further refined these into engineering characteristics that drive detailed design attributes. Constraints are also listed here as requirements for completeness. A sampling of the highest-level requirements and

some refinement are presented here for this report. These will need further review from customer interviews and QFD refinement prior to execution as described in the discussion above.

Verification methods are defined as Design (D), Test (T), Inspection (I), and Analysis (A). Requirements are further defined by categories as Inputs (I), Outputs (O), Functional (F) and Non-functional (NF).

Requirements Derived from Objectives and Constraints

Table 3: Requirements derived from objectives and constraints

Requirement	**Verification** (D, T, I, A)	**Category** (I, O, F, NF)	**Stakeholder** (appendix, bullet)
DTED shall refurbish B131 Rm 1450 in FY17	I	NF	D
DTED shall refurbish B131 Rm 1450C in FY17	I	NF	D
DTED shall refurbish B131 Rm 1460 in FY17	I	NF	D
LLNL shall install the ACE Facility in B131 Rm 1450C and 1460 in FY17	I	NF	D
LLNL shall commission the ACE Facility in B131 Rm 1450C and 1460 in FY17	I	O	D
DTED shall provide the existing essential functional capabilities of the JASPER target fabrication facility at the end of the refurbishment project	I	O	F
DTED shall maintain the existing quality standards for JASPER target fabrication facility at the end of the refurbishment project	I	O	F
DTED shall provide the Moore precision CMM for JASPER target fabrication	I	F	F.3.a.iv
DTED shall maintain adequate JASPER target fabrication capacity to support continued testing a the NNSS during the refurbishment project	I	NF	F
DTED shall maintain the existing production capacity for JASPER target fabrication facility at the end of the refurbishment project	I	O	F

Requirements Derived from Key Performance Parameters

Table 4: Requirements derived from key performance parameters

Requirement	**Verification** (D, T, I, A)	**Category** (I, O, F, NF)	**Stakeholder** (appendix, bullet)
Experimental Program – Steady supply of targets			
DTED shall provide the capability to supply high fidelity JASPER targets during the refurbishment	D	F	F
DTED shall provide the capability to assemble simple JASPER targets during the refurbishment	D	F	B
Data Quality – Assembly environment			
DTED shall provide humidity control of the assembly area	D	F	A.2.a
DTED shall maintain humidity in the assembly area <15%RH	I	F	D.2.a
DTED shall provide temperature control of the assembly area	D	F	A.2.a
DTED shall maintain temperature in the assembly area +/- 1°C	I	F	B.4.c
JASPER shall provide cleanliness control in the assembly area	D	F	A.3.a
JASPER shall maintain cleanliness on the assembly table less than 10 particles of 5um maximum dimension or larger per square centimeter	I	F	A.4.c
Data Quality – Retain capabilities for assembly, testing and validation			
DTED shall provide the capability to assemble targets to 25um accuracy	I	F	B.2.b.ii
Operations – Adequate space for efficient operations and maintenance			
DTED shall provide adequate space to have multiple targets in various phases of assembly	A	F	A.2.e
DTED shall provide adequate storage space for parts and assemblies	I	NF	A.2.f
DTED shall provide a facility of nominally 1700 ft^2	I	F	A.2.f
DTED shall provide a crane with at least 7.5ft hook height	D	F	A.2.c
DTED shall provide a crane with at least 500lb capacity	I	F	D.2.b
DTED shall provide a crane with fine motion controls (no overrun)	T	F	A.2.c
DTED shall provide a crane with no overrun	T	F	A.2.c

Requirement	Verification (D, T, I, A)	Category (I, O, F, NF)	Stakeholder (appendix, bullet)
DTED shall provide the JASPER target fabrication facility with access controls	I	NF	A.2.d
DTED shall provide access to a machine shop for the JASPER target fabrication facility within 100yds of the facility	I	NF	F.4.b
DTED shall provide a facility layout such that adequate space is provided for machine maintenance access	I	NF	C.3.a

9. FUNCTIONAL ARCHITECTURE

The operations of the JASPER target fabrication facility are discussed in Section 4 using Figure 6. The first three levels of the functional architecture are shown below. The colors in the diagrams are used consistently throughout to represent the functional tasks performed and the area of the facility where they are performed.

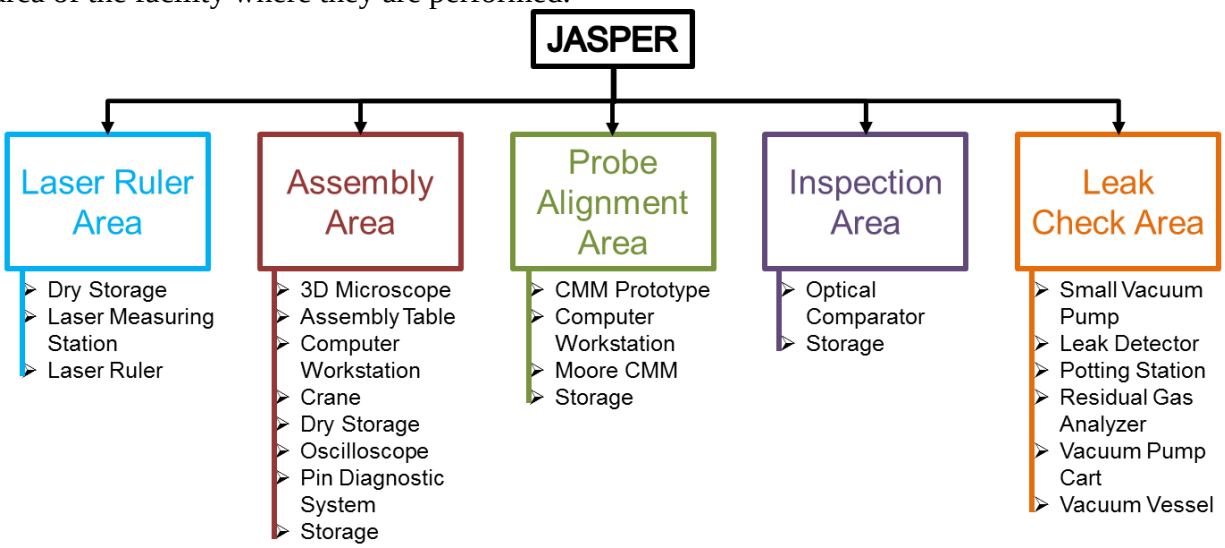

Figure 11: JASPER Targer Assembly Facility Functional Architecture

10. ORGANIZATIONAL and BUSINESS IMPACT

The intent of moving the JASPER target fabrication facility during the general B131 High Bay refurbishment is to minimize changes to the organization and minimize the impact to operations (business). This approach also meets the need to install the ACE Facility in a new location. The proposed solution provides for some consolidation of the JASPER work area from two rooms to one while retaining the functional capabilities and environmental characteristics of the original room, as detailed in Section 3. The new location has been arranged to gain some efficiency improvements by locating storage and parts near where they are needed, but this gain is recognized to be small. Additionally, adequate space has been provided around equipment to move other equipment in and out of the room, or perform maintenance on the existing equipment. A new crane has been selected with adequate load margin, and it will be serviced under the same plan as the existing infrastructure cranes.

The JASPER program will be impacted during their move. The technicians assigned to JASPER are in the best position to sort, package, move and reorganize their work area. Some support will be provided to move and seismically anchor storage cabinets and work benches, but most of the small items must be moved by the knowledgeable technicians. Account numbers will be provided to fund these efforts, but it is anticipated that work will be impacted for about two weeks due to the move. It is expected that planning these activities well in advance and communicating them with the JASPER Program will help reduce any assembly schedule impacts.

During this same period, the Moore CMM will be unavailable. It must be disconnected, moved and recommissioned. This is not a trivial task, but LLNL's Machine Tool Services technicians have previous experience with the machine, and it is believed that it can be moved and successfully recommissioned. Further risks associated with this move are discussed in the subsequent section.

11. RISKS and READINESS ASSESSMENT

As with any modernization project, there are risks in disturbing the status quo. These risks need to be identified up front and engineering solutions provided where feasible. The new systems or concepts of operation should reduce the overall risk compared to the old process, to the extent that management funds adequate measures to reduce the risk or management knowingly accepts the higher risks involved in the new product. The systems engineering methodology is applied to identify these risks up front while time exists to evaluate and mitigate them. Risks are then reduced to an acceptable level, though they are never totally eliminated.

Three technical risks have been identified with moving the JASPER target fabrication facility to be evaluated here:

- Moore CMM – move and recommissioning
- Environment – new room is in fact different
- Crane – use was underdefined and new system is too small

A standard LLNL approach is applied to evaluate these risks. First, their unmitigated probability is determined and consequences are evaluated for personnel, equipment/experiment and the external environmental (see Table 5 for definitions). Using the matrix and definitions below, mitigations are then determined until the probability/consequence combinations are

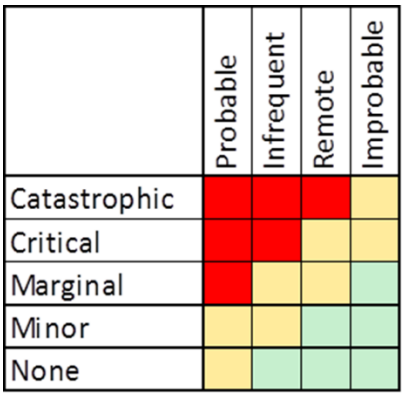

Figure 12: Risk Evaluation Matrix (red and yellow risks should be mitigated until the risk is acceptable - green)

acceptable. In general, any mitigation reduces the probability or consequence one level. It is unusual for a single mitigation to affect both probability and consequence, or reduce either more than one level, though this is allowed if the argument is convincing. The Risk Matrix for the three risks explored in this report is provided in Attachment H.

Table 5: Risk Consequence and Probability definitions

Consequence	Probability
Catastrophic = A failure that may cause death (lethal dose).	**Probable** = Expected to happen in the life of the project.
Critical = A failure that may cause severe injury/illness, major damage >$10M, >2 months delay, or exceed regulatory limit.	**Infrequent** = Could happen in the life of the project. Controls have significant limitations or uncertainties.
Marginal = A failure that may cause minor injury/illness, significant damage >$1M, >1 month delay, or exceed administrative limit.	**Remote** = May happen in the life of the project, but not expected. Controls have minor limitations or uncertainties.
Minor = Failure not serious enough to cause injury/illness but may cause minor damage (>$100k) or delay, or unplanned exposure below administrative limits.	**Improbable** = Extremely remote possibility that failure will occur in the life of the project. Proven controls are in place.
None = No hazard for personnel, no damage above 100k$, or no delay.	

12. REFLECTIVE ESSAY

I had been working on this project for several months before taking the Systems Engineering course. I took this opportunity to reset all my prior assumptions and decisions, and address this project from a fresh perspective. I had intended to arrive at a fresh recommendation, not drive this project to validate my previous one. Though I tried to keep my analysis pure, I am not sure I was successful as I arrived at the same place.

Through this process, I did identify and interview new stakeholders, and used the voice of the customer process to conduct new interviews and document actual conversations. This was much more thorough than my first attempt where I mentally coalesced various conversations to develop requirements. During this process, I developed a much deeper understanding of the challenges inherent in building JASPER targets, which resulted in a much more sympathetic view of their concerns and acceptance criteria. I understand their ties to the Moore CMM and the desire to maintain continuity of the assembly process to minimize uncertainty in their experimental results, but they are one failure away (with multiple failure mechanisms) from a major disruption to their work. They accept this and are working much too slowly to find an alternate solution – they will focus on that crisis when it happens.

I struggled with the reasoning to develop so may figures that each seemed 80% redundant (context diagram/process flow diagram/sequence diagram/use cases and layouts/functional architecture), but through conversations with my advisor came to accept that the course assignment was to use all the tools, not just a narrower set that applied to this project. The report may seem redundant in several areas, but I did learn a little bit more about each analysis technique that will be beneficial in the future.

As an engineer, I found the Quality Function Deployment tool and associated "The House of Quality" report most fascinating. This is a great tool to convert customer expectations into engineering characteristics with a visual representation of how the characteristics influence each other. The ability to iterate and drill down into more detailed requirements is powerful. This tool provided my single, largest "ah, ha!" moment of the course and I look forward to using it in the future.

I used many of the tools presented in this class in my first approach to this project, so perhaps it is not surprising that I arrived at the same recommendation. What I have at the end of this report is a much more thorough understanding of the stakeholders and requirements, and a much more defensible recommendation. Systems Engineering is about the journey, not just the destination.

Attachment A

Rocky Beckelman, JASPER Lead Technician

Given: **DTED needs to refurbish the two rooms currently occupied by the JASPER program in the B131 High Bay.**

1. Describe the work performed by the JASPER team in the B131HB.
    a. JASPER is a key scientific tool for investigating the physical properties of metals and actinides, specifically for studying plutonium at conditions relevant to the performance of nuclear weapons. The facility provides a much more cost-effective option for gathering data in comparison to underground testing. On September 25, 2012, Livermore researchers fired the gas gun's 100th shot in an experiment that further improved their understanding of plutonium's properties and ushered in the next era of plutonium-based research.
    b. Some simple targets take a week to build, some take 6-8 weeks.
2. What capabilities of the current work area are essential to the JASPER project?
    a. Temperature / Humidity Controlled Environment
    b. Moore Measuring Machine used to locate and focus Photonic Velocimetry Probes
    c. Overhead Crane (clarified to include crane characteristics in follow-up interview)
    d. Limited room access
    e. Large work area
    f. Plenty of storage for parts and assemblies
3. What does your ideal work space look like?
    a. Clean – no airborne or surface particulates (clean hood?) with a clean floor
    b. Low background noise – the current room has a lot of ventilation noise
    c. A place where I can be proud to bring in customers
    d. A crane with a retractable pendant or remote controls
    e. I need storage area and room for multiple assemblies, with controlled access
4. What capabilities do you need that you currently don't have?
    a. Reliable temperature/humidity controls
    b. Improved lab lighting
    c. A cleaner facility, floors, fewer particulates in the air
5. What does your project's schedule look like over the next year?
    a. Currently scheduled for the first half of the upcoming year are two "Hot" (plutonium) Shot Targets
    b. Eight to Ten Surrogate Shots (non-plutonium) are scheduled
    c. Currently in negotiations with Physicists for a possible add-on of two to five additional "Hot" Shots Targets, along with three to five additional Surrogate Shots
6. When is the work load lightest or most critical?
    a. JASPER work load is based around a Shot Schedule put together by JASPER Physicists and the JASPER Engineering Team. The work load as far as the number of shots is at its lightest is when we are in the developmental stage of a particular target design. JASPER targets are constantly evolving to meet Physics requirements. Jasper work load is at its highest once the target reaches the

fabrication stage. Once at this stage there is usually no less than three, and up to eight targets required for any given series of shots

Attachment B

Jeff Haslam – JASPER Lead Engineer

Given: **DTED needs to refurbish the two rooms currently occupied by the JASPER program in the B131 High Bay.**

1. Describe the work performed by the JASPER team in the B131HB.
    a. Developing concepts for targets requires a lot of iterations. Our requirements are not well defined. It truly is research and development.
    b. We set up probes and fibers and see how they perform. We look for cross-talk between the channels and establish relative timing. We also spend a lot of time on alignment concepts.
    c. We build up a target assembly and ultimately place it in a primary target chamber (a vessel 2' in diameter and 3' long) for testing. For data analysis, we need to know the flatness, tilt and normal position of the target relative to the gun.
    d. Building 1 hot shot target can take 4-6 weeks. Building a second identical target at the same time takes 75% longer.
2. What capabilities of the current work area are essential to the JASPER project?
    a. Temperature and humidity controls are not ideal
    b. Moore CMM
        i. Z action to find range of focus, requires 50-100um
        ii. XY action to set probes to 25um, relative to the sample position
        iii. If it died, we'd try to find replacement parts to fix it. We could go to HEAF for simpler targets.
3. What does your ideal work space look like?
    a. Reliable temperature and humidity controls.
4. What capabilities do you need that you currently don't have?
    a. We plan to add a laminar flow hood or work bench
    b. In the future, we may need to support future target validation with radiometry probes.
    c. Future instruments may have tighter room temperature controls.
5. What does your project's schedule look like over the next year?
    a. The shot schedule for CY17 is up in the air. We have two hot shots planned in the first half of the year and two more shots in late 2017 including larger target qualifications.
    b. The schedule is jammed – stuff always gets added on. We also get random delays from the Nevada facility. Various issues wreak havoc on our plans.
6. When is the work load lightest or most critical?
    a. Open time tends to get filled.
    b. Moving twice is disruptive.

Attachment C

Jeff Bear – LLNL Lead HVAC Maintenance Technician

Given: **DTED needs to refurbish the two rooms currently occupied by the JASPER program in the B131 High Bay.**

1. Describe the work performed by the JASPER team in the B131HB.
    a.
2. What capabilities of the current work area are essential to the JASPER project?
    a. We periodically get calls when the dehumidifier stops working. The humidity sensors alarm on the higher humidity and when Rocky comes in he gives us a call to come reset or repair the system.
    b. The dehumidifier is 30 years old and maintenance is no longer supported by the manufacturer. We can still get parts, but it takes a lot of work.
3. What does your ideal work space look like?
    a. Most of the rooms serviced by this dehumidifier don't need humidity controls. We could replace it with a smaller unit that just services the JASPER rooms. We could also build a small work enclosure that would provide the environment necessary just for JASPER's assembly work and not condition the whole room.
4. What capabilities do you need that you currently don't have?
    a. New units are more reliable and also much more efficient.
5. What does your project's schedule look like over the next year?
    a.
6. When is the work load lightest or most critical?
    a.

Attachment D

Lou Bertolini, DTED ADL for Operations

Given: **DTED needs to refurbish the two rooms currently occupied by the JASPER program in the B131 High Bay.**

1. Describe the work performed by the JASPER team in the B131HB.
    a. Primarily assembly of targets
        i. Very small pieces with windows and sensors attached to the sample
        ii. A lot of preassembly fit-up and prototyping
        iii. Some of the materials cannot be exposed to regular air
        iv. From here, the samples go to NNSS
2. What capabilities of the current work area are essential to the JASPER project?
    a. Humidity must be as low as possible, less than 15%. They learned from a previous experiment that if this is not controlled, the sample is becomes contaminated and its properties change. Their recent problem shut them down for 2 years to clean it up so this is not trivial. They changed their process and some of the material is now encapsulated. They have not done any formal tests to know where the acceptable limit is, or what their requirements are, but they know the current process is good enough.
    b. Hoisting of less than 500 lbs.
    c. The Moore Machines, which is old and could fail at any time.
3. What does your ideal work space look like?
    a.
4. What capabilities do you need that you currently don't have?
    a. They need a replacement for the Moore
    b. They don't really have a lot of money, so the current process is adequate and they will continue to limp along shot to shot
5. What does your project's schedule look like over the next year?
    a. The project schedule more than two years out is totally unknown
6. When is the work load lightest or most critical?
    a. They have a handful of shots this year, similar to FY15 and FY16
    b. There is a potential for down time as material become available

Attachment E

Derek Clark, Facility Work Coordinator

Given: **DTED needs to refurbish the two rooms currently occupied by the JASPER program in the B131 High Bay.**

1. Describe the work performed by the JASPER team in the B131HB.
    a.
2. What capabilities of the current work area are essential to the JASPER project?
    a.
3. What does your ideal work space look like?
    a.
4. What capabilities do you need that you currently don't have?
    a. They have not asked for anything new. They have everything they need.
5. What does your project's schedule look like over the next year?
    a.
6. When is the work load lightest or most critical?
    ○

Attachment F

Albert Lee, Program Manager

Given: **DTED needs to refurbish the two rooms currently occupied by the JASPER program in the B131 High Bay.**

1. Describe the work performed by the JASPER team in the B131HB.
    a. The facility fabricates target assemblies and prepares them for delivery to Nevada.
    b. We also perform fit-ups with the primary target chamber which requires precision measurements, often to 5-10um
    c. We also evaluate various designs for diagnostic probes and figure out how to help vendors fabricate them correctly.
2. What capabilities of the current work area are essential to the JASPER project?
    a. We build and inspect target assemblies. If the target assembly doesn't work correctly, it can set us back years to fully recover
    b. Moisture controls are critical – I cannot tell you if it is 30% or 100% of the problem, but it is key
3. What does your ideal work space look like?
    a. We do not have to have the current room, but we need all its capabilities
        i. Cranes
        ii. Workbenches
        iii. Environment
        iv. Moore machine
            1. We need the same capabilities and accuracy. We are underutilizing the machine's capabilities now, but until we prove a replacement works for all our needs, I need this machine and don't want to limit our abilities.
            2. There is a custom-built replacement, but I don't know its lead time or if the cost is suitable.
4. What capabilities do you need that you currently don't have?
    a. We need to be able to inspect the target assembly without opening the assembly. This requires an integrated ability to test it – a couple of benches, currently an eye-safe laser.
    b. Machine shop
5. What does your project's schedule look like over the next year?
    a. We are doing 3-4 hot shots, vice the 7-8 historically.
    b. We are building few JASPER targets, but could build development targets here vice at HEAF.
6. When is the work load lightest or most critical?
    a. July 2017 would be best.

Attachment G

Brad Martin, B131HB Manager, Technician Supervisor

Given: **DTED needs to refurbish the two rooms currently occupied by the JASPER program in the B131 High Bay.**

1. Describe the work performed by the JASPER team in the B131HB.
    a. They have consistent full-time work
    b. They build multiple targets each year for testing at NNSS
2. What capabilities of the current work area are essential to the JASPER project?
    a. Crane
    b. Moore Machine
    c. Mechanical assembly areas for bonding, vacuum testing, inspection
    d. Shipping and packaging areas
3. What does your ideal work space look like?
    a. Current space is adequate, they need to include room for their electronics group
4. What capabilities do you need that you currently don't have?
    a. They are currently very well equipped
5. What does your project's schedule look like over the next year?
    a.
6. When is the work load lightest or most critical?
    a. They have some pauses come up occasionally, but they are unpredictable

Attachment H

Risk Matrix

Primary System	System or Subsystem	Failure Mode	Cause	Effects	Personnel Consequence before Mitigation	Equipment/ Experiment Consequence Before Mitigation	Environmental Consequence before Mitigation	Probability of Occurrence before Mitigation	Mitigation Controls in Place	Personnel Consequence after Mitigation	Equipment/ Experiment Consequence After Mitigation	Environmental Consequence after Mitigation	Probability of Occurrence after Mitigation
JASPER Target fabrication facility	Moore CMM	Loss of precision assembly capability	Machine is damaged due to relocation and cannot be recommissioned	Components cannot be precision located in assembly	None	Critical	None	Remote	- Use experienced technicians to relocate/recommission (prob) - Provide plan for temporary replacement machine (cons) - Provide plan for permanent replacement machine (cons)	None	Minor	None	Improbable
	Environment	Damaged test materials	High humidity in assembly area	Changed material properties of test specimen	None	Marginal	None	Probable	- Control humidity to <15% (prob) - Monitor humidity continuously (prob) - Return parts to dry storage if humidity raises (cons)	None	Minor	None	Remote
		Incorrect assembly	Temperature fluctuations	Changed material dimensions	None	Marginal	None	Probable	- Control temp to +/- 1C (prob) - Monitor temp continuously (prob) - Cease assembly until temp stability restored (cons)	None	Minor	None	Remote
	Crane	Inadequate load capacity	Future target assemblies are heavier	Crane capacity is inadequate	None	Minor	None	Remote	- Procure crane with capacity margin (cons) - Provide for easy replacement of hoist (cons)	None	None	None	Remote