HIGH BAY CAPACITY UTILIZATION TOOL

A Senior Project submitted to
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San Luis Obispo

In Partial Fulfillment
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Bachelor of Science in Industrial Engineering

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ABSTRACT

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Northrop Grumman's Space Park facility has many inefficiencies in their high bay scheduling processes. Additionally, it is very hard for project managers to figure out the capabilities of each high bay in order to schedule their specific project. The purpose of this project is to develop a tool that can be used across the facility to easily create projects, assign projects, view room capabilities, and view a master schedule of the rooms.

After researching commercially available tools, our approach to designing this system was to use tools that are already utilized at the facility (Microsoft Suite and Tableau) and engineer the system to do exactly what we need it to do for this facility. The design is a relational database managed in Microsoft Access that links to Tableau for a detailed schedule for all the rooms along with facility layouts on Microsoft Visio to show each facility at any time. These three programs are tied together with a user interface in Microsoft Access and available across the entire network at the Space Park facility via Sharepoint.

While our system would have higher initial cost to train employees on, it would save significant operating costs each year. If this system were to be installed and utilized into Northrop Grumman's current operations, we estimate a cost savings between $10,000 and $25,000 over a ten year period.

However, we ran into problems with the implementation of our tool due to having to use assumed data for our project. Although it is possible to expand this system, it is a lengthy process to add parameters for rooms and change the base layout of our design. Our largest recommendation for this system is that Northrop Grumman uses the base layout of our system (including the relational database design, user interface, and data visualization) to create a new system that has actual parameters of the room. This will yield the same results as installing the system that we have developed.

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I. Introduction

Northrop Grumman is an aerospace and defense contractor. Currently, they are in the middle of a modernization effort for their M1 and M2 buildings at their Space Park manufacturing facility in Redondo Beach, CA. As part of this effort, they are making a push to develop a more integrated factory throughout all levels of production. The scope of this project grew out of the need to track high bay space utilization and capabilities at the Space Park facility. The current method stores this information in multiple documents that vary between the different high bay managers. Because they are not consistently maintained employees rely heavily on verbal communication to discern which high bays have which attributes and whether there are programs in them or not.

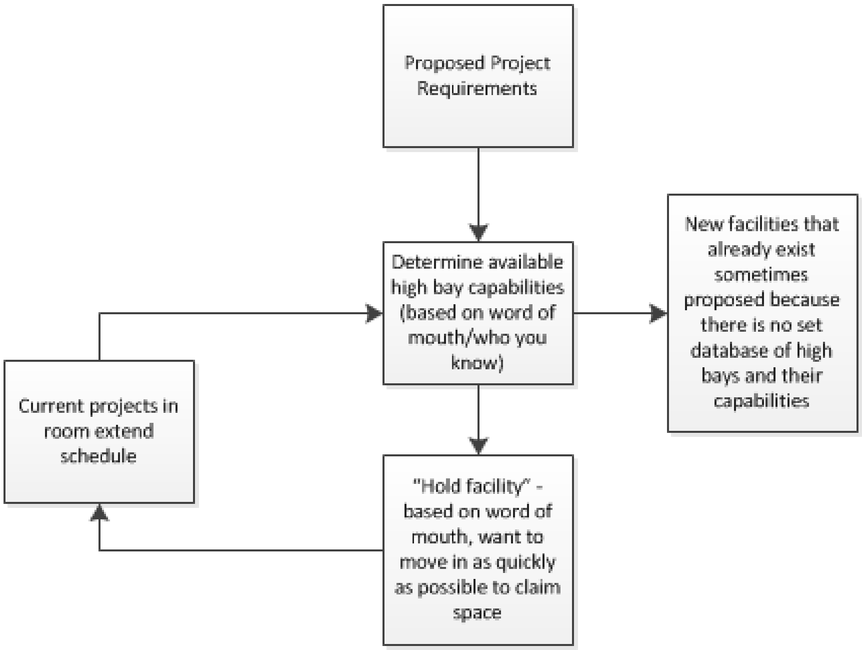
As a result, they need a tool to maintain high bay capabilities, space utilization, and project scheduling in real-time. The objectives of the tool this project aims to create are as follows:

- Track space utilization at any given date
- Determine high bay availability based on program requirements
- Suggest high bay upgrades when appropriate
- Update instantaneously as high bays/programs change
- Support scalability
- Support multiple users at once
- Provide user support manual

To solve this problem, the facility information and the relationships between its components must first be understood. From this, the overall design of the tool can be created so as to ensure it contains the proper functionality. Careful analysis of design alternatives must be completed next before selecting the final candidate for prototyping. Once the prototype is complete it will be populated with sample data and tested for bugs. Following testing, the final product will be handed to Northrop Grumman for the final phase of implementation.

II. Background (includes **Literature Review**)

Since our project for a high bay capacity utilization tool is a system improvement process, it is important to map out the current system that the company uses. To do this, we asked our contact to detail the entire as-is process and share all the common problems that are faced. The main process steps are defining requirements, determining high bay capabilities and availability, and holding the facility for the program.



1. Defining Program Requirements: In this step, the proposal team member comes up with requirements for a program. This program can often have multiple phases and requirements, so it is broken down into several aspects. For this step, there is currently an excel template that the proposal team member can fill out, however this often takes some time due to the required specifications are not exactly known.
2. Determining High Bay Capabilities and Availability: After the specifications have been made, the proposal team member must match these specifications to a high bay in the facility. This requires personal contact with each facility owner, a response time delay, and often a non-standardized and non-accurate spreadsheet of current facility capabilities. It usually takes about a week to check each high bay's capabilities in total, and there may be several high bays that need to be checked before a solution is found. Additionally, since each program historically has vastly different requirements, either a high bay must have a few of its capabilities upgraded or an entire new high bay is built to match this project. This is very costly and there is currently no way to see which highbay will be the easiest to upgrade to match the program. Having an inexperienced engineer or

proposal team member working on the project can add to the chances that they will initiate costly and unnecessary upgrades without checking all the high bays.

3. Lastly, once a high bay is matched, upgraded, or created to match a program, the room is held, or reserved for that program until the current program finishes. Since almost all programs are extended beyond their projected end times, this creates a chain effect that delays the start time of projects that are scheduled in a high bay, which delays the end time, and so forth. Next, a program with a higher priority often completely replaces a program with a lower priority, and the lower priority program is not rescheduled at all. Both of these happen with no standardized notification procedure to the program engineers, which causes their programs to be delayed or cancelled in a room without them knowing. There is no official schedule or documentation that records all the projects that are being held, and it is often just unofficially recorded on a who-you-know and word-of-mouth basis.

Overall, our group sees many improvements that can be made on this entire process. With an overall system design and standardization goal, we believe that we will be able to create and optimize this system.

Literature Review

In order to fully understand our problem statement and begin designing prototypes, we researched articles on topics of space scheduling, resource allocation, equipment tracking, and project matching. In addition, we wanted to look at different alternatives, user interface designs, and eventually start to use sources to teach ourselves additional tools that we may need.

This problem primarily deals with program management. People need to know what is available and where programs can go in order to plan appropriately. In engineering management, planning is one of the most important aspects to success [14]. By planning correctly, risk and uncertainty can be mitigated as much as possible. From the problem statement it is apparent that Northrop Grumman is in need of some type of centralized project management tool that is easily accessible to multiple users. Manufacturing Execution Systems (MES) are one such tool that offer a similar functionality to the requirements of this project. MES offers the ability to improve working efficiency by allowing instantaneous tracking of WIP, equipment, and space [11]. In the case of MES Factory Server, information is stored on a database where it can be accessed and edited by users with the appropriate authority at all times. A system such as this could be the basis for the final tool produced by this project. Furthermore, the overall need for such a tool is emphasized in the study *How Knowledge Management Impacts Performance: An Empirical Study in Chinese Knowledge-Intensive Enterprises* [12]. Knowledge translates directly into performance. When knowledge is not stored in a centralized location (e.g. a database) where anyone can use it the overall organization suffers from an impact on performance. Indeed, there is an economic relationship between the two. Knowing this, the development of this tool is further justified and in fact this economic relationship as it applies to Northrop Grumman will be further clarified as part of this project's business case.

One of the major objectives of this project is to reveal the impact of scheduling changes as they happen. One way to accomplish this would be through a Gantt chart. This would allow the visualization of program schedules and reveal any conflicts. LiveGantt, an interactive visualization tool, is one of the options being explored in areas such as this [13]. Its scalability and ease-of-use allow the user to easily test the effect of new schedules in order to determine the optimal order. In the case of manufacturing with a finite number of high bays, this represents one potential method of viewing changes.

The Scientific Article "Factors and procedures used in matching project managers to construction projects in Bangkok [1]," may be very useful for the matching component of our design. While not directly related to our project, this article may be useful for analyzing matching criteria. The article details the process of matching Project Managers to Construction Projects based off of their characteristics. For our project, this matching criteria could be applied to match high bays to Projects.

Radio Frequency Identification Systems (RFID) are commonly used in manufacturing facilities to track inventory. The article "Design of a RFID case-based resource management system for warehouse operations [2]," details the uses of such systems. They can be used in the form of very small chips placed on products- which send electronic signals to a Reader. For our project, RFID's could possibly be used to track each project, and its location in the high bays.

Plant capacity and utilization are two important metrics for facilities managers to understand the efficiency of their plant. These metrics are discussed in the article "Measuring Plant Capacity, Utilization and Technical Change: A Nonparametric Approach [3]." This article explains the measures used to determine efficiency of a plant, which can be applied to our project by measuring the efficiency of the high bays.

The main component of our project is scheduling projects- which is a common problem across all industries. A universal tactic for improving schedules is to reduce the complexity of them. More specifically, the article, "Reducing Scheduling Complexity Improving Primary Care Access [4]," explains theories to improve scheduling of doctor appointments in health clinics. One such strategy is the use of "Building Blocks." This is done by scheduling the length of each appointment as multiples of a common unit. For example, each appointment is scheduled in multiples of 30 minutes- they can be 60, 90, 120 or longer, but must always be a multiple of 30. Safety times are added, for example an appointment that is projected to last 50 minutes would be scheduled for 60, leaving 10 extra minutes in case it needs to be extended. When this method is applied, there are common start and end times- such that multiple appointments will finish at the same time, leaving multiple rooms available to be used for the next time block. The safety times prevent future appointments from being delayed. This method of Building Blocks and Safety Times could be applied to our Highbay scheduling, with a building block length of three or six months. This would reduce the number of delayed projects, and decrease the complexity of the overall schedule.

Before developing our own prototype, we first looked into commercially available, over the shelf tools. One example of these tools for project scheduling is called *Aurora*, which is used by both NASA and Boeing. The success of this highly regarded tool is highlighted in the article, *"Intelligent scheduling at NASA: Application to ground operations at Kennedy Space Center* [5].*" Aurora* uses artificial intelligence to efficiently plan projects with thousands of processes and constraints- drawing from a combination of programmed algorithms and historical human suggestions. In addition to this, it uses a "Multi-Pass" method to allocate resources, which can generate more efficient plans for projects. In a benchmark test by Boeing, *Aurora* generated a project timeline 20% shorter than *MS Project.* Finally, *Aurora* provides reasoning for each decision- showing an explanation of its results by analyzing time and resource constraints. Overall, we believe that *Aurora* could be a very valuable asset to Northrop Grumman for project scheduling and resource allocation. Other possible solutions exist in industries outside of manufacturing. One specific industry that has potential is the healthcare industry. Hospitals themselves deal with extensive scheduling problems and as a result have developed their own approaches [15]. One such example exists a the UVa Hospital where personnel scheduling is determined through a SQL database that considers preferences such as vacation time and seniority. This is analogous to the situation Northrop Grumman faces where programs must be scheduled based on their requirements and relative weights. A similar program is used to schedule patients at another hospital [16]. In this case, the open-source software Minizinc is used to provide the logic used to determine the optimal schedule. Such open-source software offers the possibility of being tailored to fit the specific needs of other industries, as well. Next, we looked into utilizing Tableau for visualization methods. For this, we found an article from the 2012 ACM SIGMOD Conference Proceeding titled "*Dynamic Workload Driven Data Integration in Tableau* [22]". From this article, we looked towards utilizing similar techniques to integrate a visualization in Tableau that work work alongside our design, or even using Tableau as our front-end visualization to manipulate and visualize our database.

Matching projects with different resources is an important part of our Senior Project. The article, "*The Study of Matching Theory and Methods Between Management System and Information System in IT Project of Manufacturing* [6]," uses Neural Networks to match manufacturing projects to IT Systems. For this matching, there are 16 criteria that each project is rated on, each with different weights. The overall system chosen for each project is based on a weighted average of these 16 criteria. For our project, highbays could be chosen based on a weighted average model like this one. For example, we could give weights to the following categories: Clean Room Level- 0.4, Security Class- 0.3, Available Power-0.1, Crane Capacity-0.2. Using this weighted average would create a standardized, systematic procedure for matching projects to highbays. Looking forward into a heuristic method of matching, we found steps in an article, "*Equipment Assignment to Multiple Overhaul Blocks in Series Systems"* from *Journal of Quality in Maintenance Engineering* [21]", that utilized a QuickSort algorithm in a hierarchical chart to result in a unique threshold value for each grouping. This same method can be applied to sort the available high bays in order from best match to worst match.

Capacity measurement is important to understand the capabilities of a facility, as well as the level of utilization it is being used for currently. Capacity is thoroughly explained in the scientific article, "*The Use of a Scheduling System for Materials and Capacity Requirements in a JIT Factory Environment* [7]." As we recall from our Production Planning (IME 410) coursework, schedules generated by MRP assume infinite capacity, which can cause problems in real world applications. This article uses an Manufacturing Control Code (MCC) simulation that analyzes shop floor space requirements, personal requirements, and fixtures for each product to be manufactured. To be applied to our Senior Project, we could analyze the personnel requirements of each project, and assign high bays based off their personnel capacity, rather than just square footage.

Scheduling of tasks is very important for Northrop Grumman's Factory Modernization project. They are in the process of upgrading several buildings, which makes high bays unavailable for certain time periods. Likewise, maintenance scheduling is also important for projects, as discussed in the article, "*Multi-criteria classification for prioritization of preventive maintenance tasks to support maintenance scheduling* [8]." It discusses the importance of prioritizing shutdowns based on three criteria. First, the delay percentage - calculated as the amount of downtime divided by the period between downtimes. For example, a 3 day delay that must occur every 30 days would be counted as 10%. Secondly, business impact is considered. Business impact is calculated as the amount of time that a resource is needed divided by total time. A high bay that is used 20 hours a week would have a business impact of 50%. Third, the criticality is considered- a measure of the safety risk of downtime. Systems with a critical importance- such as fire detection receive the highest score in this category. Finally, an Analytical Hierarchy

Process is applied to find the weighted average across all categories, and which determines the schedule of downtime for each process.

Part of the challenge of Northrop Grumman's Redondo Beach facility is the high variety of projects. Reproducing efficiency and quality in low volume, high mix environments can be very difficult, as mentioned in the article, "*Multimode resource-constrained multi-project scheduling with ad hoc activity splitting.* [9]" One method discussed includes categorizing projects depending if they are able to be split into subprojects. Splitting projects reduces the resource requirements of the total system. For example, if a satellite project requires both a high level clean room and liquid nitrogen cooling, it would be very difficult to find a suitable high bay. However, if it is possible to split the project into two subprojects- one that requires a clean room and another that requires cooling, it will be much easier to store this project in multiple high bays, hence the purpose of project splitting.

As mentioned previously, the Redondo Beach facility is used for very low volume, high mix production. Standardization of high mix processes is explained in the article, "*A data based production planning method for multi-variety and small-batch production* [10]." To simply the problem, a production plan is first generated at the quarterly level for aggregate groups of products. After this has been decided, a more specific plan is generated down to specific products and months- and finally sub products with corresponding days. An approach similar to this could be used for Northrop Grumman, where high bays could first be planned on a quarterly basis for groups of similar projects. Once the groupings are decided, a more detailed plan for months and days can be generated for each high bay.

At the *6th IEEE Conference on Industrial Electronics and Applications*, a matrix-based approach to allocating resources to multiple tasks in order to produce the optimal result was discussed [18]. It does so by computing the utility of each task through the computation of two factors: completion time and expense. It is my hope to adopt this technique for application to high-bay utilization at Northrop Grumman. This way the differing attributes of high-bays can be weighed against the requirements of the various projects in order to produce the most optimal utilization of high-bay space. Similarly, the work at the *2017 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies* focused on using the genetic algorithm coupled with the Serial Schedule Generation Scheme to solve resource-constrained project scheduling [19]. A different approach than the one above, I believe this approach may work better for scheduling in the long term. Tasks are assigned durations and resource requirements. These are then compared to resource constraints to determine allocation. My focus here is on the algorithm's ability to understand that certain tasks must be completed before others. With this in mind, new projects will be scheduled after previous projects are complete. In order to integrate the space requirement into this project, the article *Improvement Algorithm for Limited Space Scheduling* considers the impact of finite space resources ons scheduling [20]. Space over time is used to help schedule tasks with varying resource requirements to most efficiently schedule a project. I think that this will be applicable to my project because the algorithm can be applied to the various high-bays and their space capacities to help place multiple projects with similar resource requirements in the same space.

Once we saw a trend leading back to developing our own system, we decided to start researching methods and programs that would allow us to do this. We started with the book titled How to Build a Big Company System on a Small Company Budget by David Vine [23]. This source explains inexpensive Internet Business Intelligence Systems to match systems of large Fortune 500 companies. It shows a simpler and cheaper way of implementing these tactics, much like what we will be doing for this project. The most useful section was the tutorial on creating a system to evaluate opportunities and risks, because this can be applied to evaluating opportunities and risks of assigning projects to high bays. Next, we looked towards utilizing our basic skills of Microsoft Access from our Data Management and Systems Design course. We looked into Microsoft Access guides along with relational database design and SQL scripting. For these, we are using Hands-On Microsoft Access by Bob Schneider [24] and SQL Practical Guide for Developers by Michael J. Donahoo and Gregory D. Speegle [25]. We have been able to utilize both of these books to create complicated form and query designs that helped us establish our Microsoft Access prototype so far. One of the primary concerns with database design is normalization of the tables [17]. By normalizing the tables the data will be best organized in a manner that avoids data loss during updates or handling of the database.

After we researched on all of these, we decided to research into developing an efficient, effective, and human-factors friendly user-interface. We believe this is a very essential part of our design because it should be both aesthetically pleasing and simple so that the user can get maximum use of it. This will also be useful when we combine our design with a Standard Operating Procedure for the use and expandability of our tool. We would like our Standard Operating Procedure for our tool to have a human-factors-friendly interface as well that ties in well with our design. To look into increasing the adaptability of our tool to cover the content and easily expand, we found an article called "*A DSPL Approach for the Development of Context-Adaptable User Interface* [26]". In this article, it is shown how Dynamic Software Process Lines are used for context-adaptability and it is explained how we might be able to make a dynamic system that can expand upon user request. Next, we looked into the articles "*The Development of Design Aid Tools for a Human Factor Based User Interface* [27]" and "*Automating the Human Factors Engineering and Evaluation Process* [29]". The first article [27] showed us many tools we could utilize to increase our user-experience. Unfortunately, many of these tools are not available in Microsoft Access, but we were able to apply the graphical and tabular methodologies. The second article [29] explained the usability of an add-on tool to Microsoft products made by Westinghouse Savannah River Company that would support human factors design. This add-on contains many tools that are mentioned in [27] that could be purchased to create a very effective user interface from a human-factors perspective. Lastly, to research into increasing the actual usability and effectiveness of our tool, we looked into “*User Interface Design with Combinatorial Optimization* [28]” and “*Research on the Usability Evaluation Technology Software Interface for Specific User* [30]”. The article on Combinatorial Optimization [28] had many details on how to combine many factors of the user interface to fully optimize it while keeping all of the desired functionalities. This will be useful because we would like to avoid making our system too complex but we still need it to have all of the functionality. The article catered to the Specific User [30] performed a survey on many different age groups comparing simplicity vs usability on a in a user-satisfaction sense. There were strong trends towards the desire for a simple user interface, however the survey concluded that it is important to have a mix of both.

III. Design (or **Theory**)

Specifications and Constraints

The focal point of our design is a database to track the project requirements and high bay capabilities. There are a number of different requirements for each project, as well as attributes of each unique high bay. Examples of the requirements and attributes are as following:

Constraint	**Project Requirement**	**High Bay Attribute**
Timeline	Forecast Start/Finish	Room Availability
Size	Length and Width	Room Dimensions
Height	Project Height	Height of Ceiling
Crane Weight	Project Weight	Crane Carrying Capacity
Crane Height	Project Height	Crane Extended Length
Door Width	Shortest Side Length	Door Width
Door Height	Project Height	Door Height
Clean Room Level	Particulates Allowed	Filter Specifications
Security Clearance	Project Security Level	Worker Security Level
Power	Power Consumption	Available Power
Temperature	Cooling Required	N2 Tanks Available

In addition to this, it is important to note that multiple projects can occupy one high bay. For this situation, the high bay attribute must meet the tightest requirement of all projects in the same room.

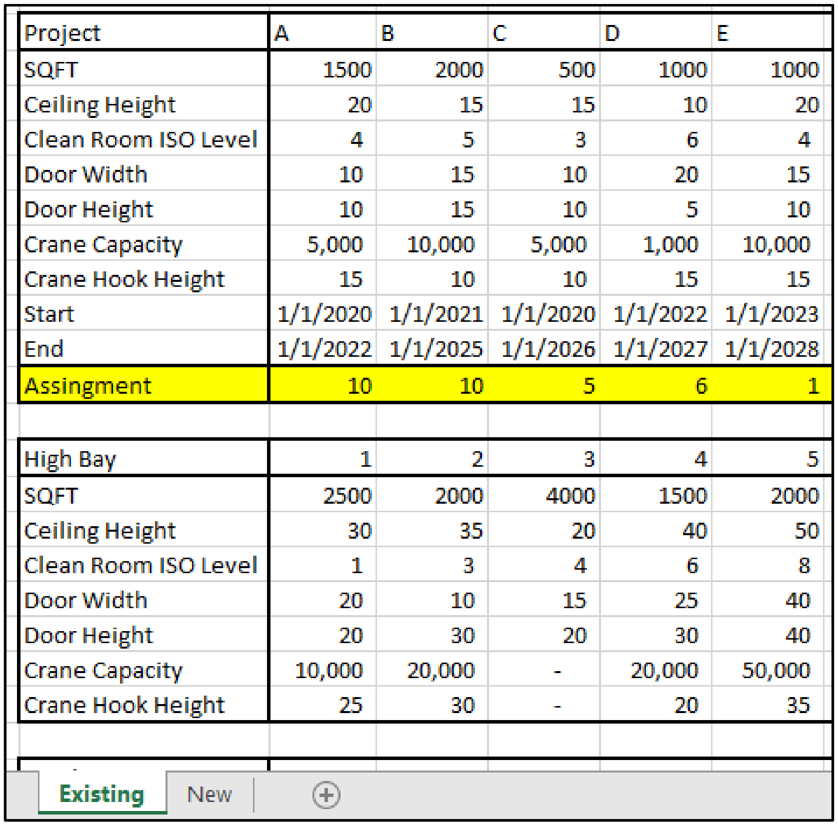
Next, our client would like a visualization of their overall capacity and utilization. This should be linked to the other databases, and will change in real-time. The database will give our client information at a glance to quickly show where there is open space in the facility and the timeframe of each project.

Capacity	High Bay 1	High Bay 2	...High Bay N
2018 Q1	% Utilization	% Utilization	% Utilization
2018 Q2	% Utilization	% Utilization	% Utilization
...2030 Q4	% Utilization	% Utilization	% Utilization

Design Alternatives

To approach this problem, we developed two alternative prototypes - one using MS Excel, and another in MS Access. We are also still researching into the plausibility of a cloud-based MySQL design that would be easily integrated into the company's system. Along with any design we create, we will also make a Standard Operating Procedure manual to go along with this tool that will allow for expansion and manipulation.

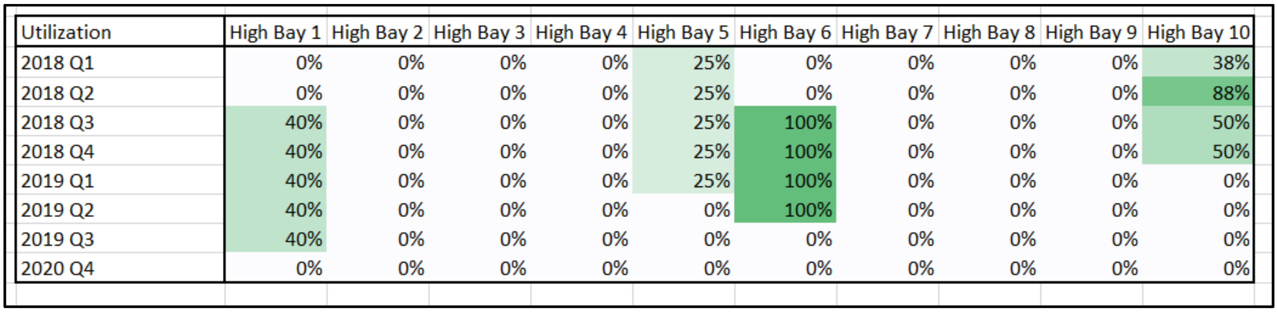
Microsoft Excel Prototype: This prototype is focused on optimal matching of projects to High Bays- using a Linear Programming Algorithm. There are two sheets- one for existing projects that are already assigned to High Bays, and one for new projects that need to be scheduled.



Project	A	B	C	D	E
SQFT	1500	2000	500	1000	1000
Ceiling Height	20	15	15	10	20
Clean Room ISO Level	4	5	3	6	4
Door Width	10	15	10	20	15
Door Height	10	15	10	5	10
Crane Capacity	5,000	10,000	5,000	1,000	10,000
Crane Hook Height	15	10	10	15	15
Start	1/1/2020	1/1/2021	1/1/2020	1/1/2022	1/1/2023
End	1/1/2022	1/1/2025	1/1/2026	1/1/2027	1/1/2028
Assingment	10	10	5	6	1

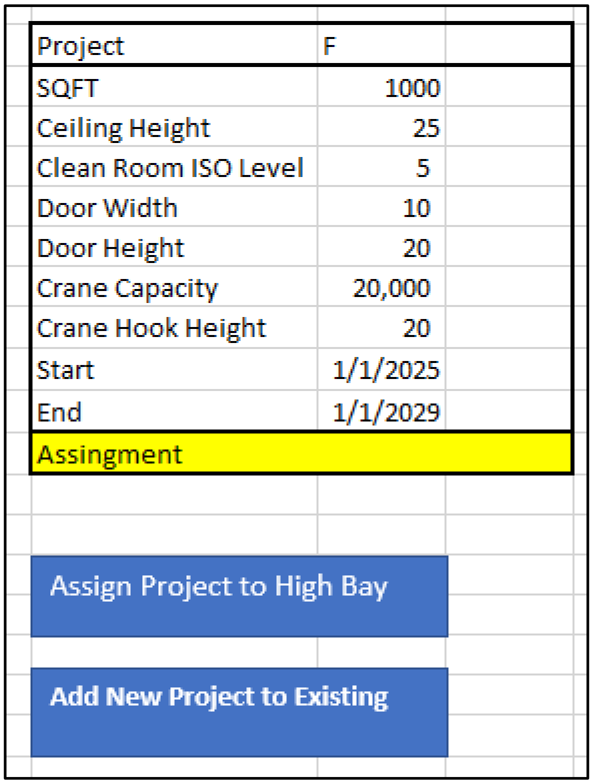
High Bay	1	2	3	4	5
SQFT	2500	2000	4000	1500	2000
Ceiling Height	30	35	20	40	50
Clean Room ISO Level	1	3	4	6	8
Door Width	20	10	15	25	40
Door Height	20	30	20	30	40
Crane Capacity	10,000	20,000	-	20,000	50,000
Crane Hook Height	25	30	-	20	35

These projects are already scheduled in their respective high bays and will not be moving.



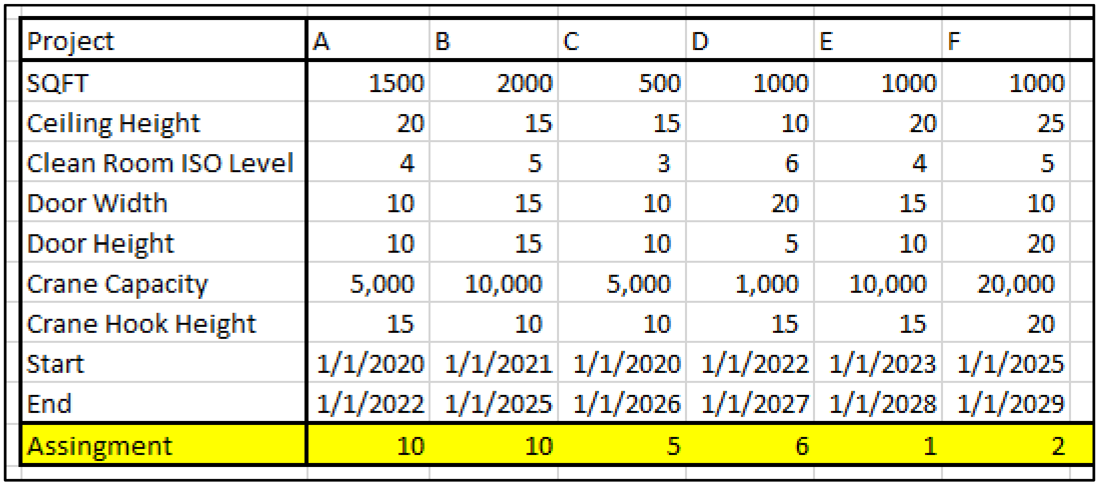
Utilization	High Bay 1	High Bay 2	High Bay 3	High Bay 4	High Bay 5	High Bay 6	High Bay 7	High Bay 8	High Bay 9	High Bay 10
2018 Q1	0%	0%	0%	0%	25%	0%	0%	0%	0%	38%
2018 Q2	0%	0%	0%	0%	25%	0%	0%	0%	0%	88%
2018 Q3	40%	0%	0%	0%	25%	100%	0%	0%	0%	50%
2018 Q4	40%	0%	0%	0%	25%	100%	0%	0%	0%	50%
2019 Q1	40%	0%	0%	0%	25%	100%	0%	0%	0%	0%
2019 Q2	40%	0%	0%	0%	0%	100%	0%	0%	0%	0%
2019 Q3	40%	0%	0%	0%	0%	0%	0%	0%	0%	0%
2020 Q4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

A table of utilization shows the overall capacity of each high bay over time. The percentages are calculated as the amount of space occupied by projects divided by the total room size.



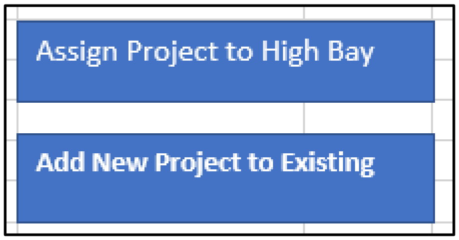
Project	F
SQFT	1000
Ceiling Height	25
Clean Room ISO Level	5
Door Width	10
Door Height	20
Crane Capacity	20,000
Crane Hook Height	20
Start	1/1/2025
End	1/1/2029
Assingment	

When a new project is to be scheduled, the requirements are recorded in a new table. Using the Linear Programming add-in *Solver*, the project will be assigned to a highbay. The objective function is to maximize the total utilization- by placing the proposed new project in one of the available High Bays. The constraints are as listed above, such that a Project that requires 4,000 sq ft cannot be placed in a High Bay that is 2,000 sq ft in size. Another constraint is the Ceiling Height- which would prevent a 25 ft tall project from being kept in a high bay with a 20 ft ceiling. Through these constraints, the *Solver* algorithm will select a high bay that matches all of the project requirements.



Project	A	B	C	D	E	F
SQFT	1500	2000	500	1000	1000	1000
Ceiling Height	20	15	15	10	20	25
Clean Room ISO Level	4	5	3	6	4	5
Door Width	10	15	10	20	15	10
Door Height	10	15	10	5	10	20
Crane Capacity	5,000	10,000	5,000	1,000	10,000	20,000
Crane Hook Height	15	10	10	15	15	20
Start	1/1/2020	1/1/2021	1/1/2020	1/1/2022	1/1/2023	1/1/2025
End	1/1/2022	1/1/2025	1/1/2026	1/1/2027	1/1/2028	1/1/2029
Assingment	10	10	5	6	1	2

After a project is matched to a high bay, it can be added to the list of existing projects using a macro. This will include the recently added project in calculations for new projects- such that "Project F" will be added to the constraints that affect the placement of a new "Project G."

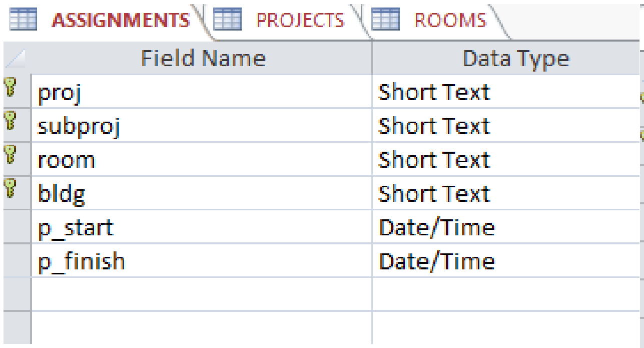


These macros allow for fast and effective user interface, especially for users that may not know how to set up Linear Programming with *Solver*. Another key function of the macros is the scalability. By adding a "New Project," to the existing projects, users can continue to utilize the prototype for years to come.

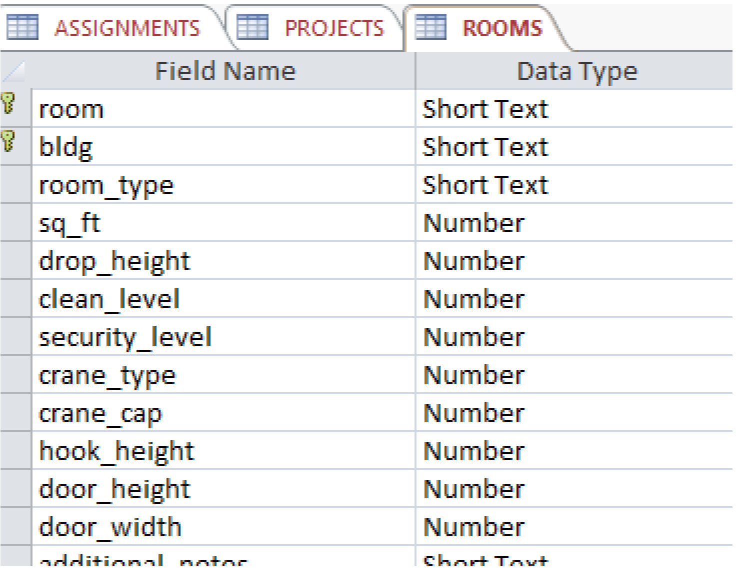
Overall, we chose MS Excel as a platform for a design alternative because of its ease of use. Because this program is already installed on the computers of our client, it would not require any additional costs to purchase software. The training costs would be minimal, as many employees are already familiar with MS Excel.

Microsoft Access Prototype: As another design option, we wanted to create a system that had a smooth user interface and also utilized relational database methodology to limit data entry mistakes and inconsistencies. This design is still in progress and we are in constant communication with our company about it to make sure that it meets their needs appropriately.

The first step of our design was designing tables. We decided on having three separate tables: ASSIGNMENTS, ROOMS, and PROJECTS. The ASSIGNMENTS table holds information regarding the length of time a project is scheduled and which room it is assigned to. The ROOMS table contains the information on the capabilities of each room.



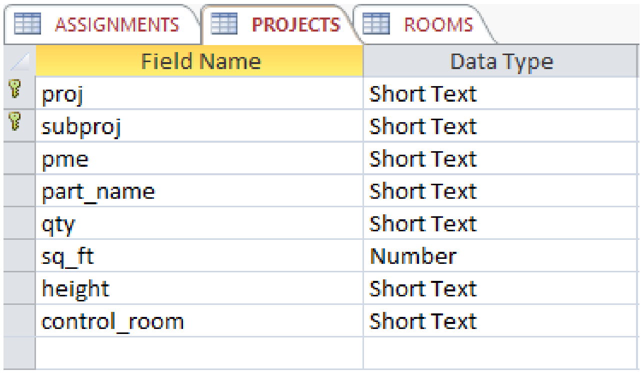
	Field Name	Data Type
🔑	proj	Short Text
🔑	subproj	Short Text
🔑	room	Short Text
🔑	bldg	Short Text
	p_start	Date/Time
	p_finish	Date/Time



	Field Name	Data Type
🔑	room	Short Text
🔑	bldg	Short Text
	room_type	Short Text
	sq_ft	Number
	drop_height	Number
	clean_level	Number
	security_level	Number
	crane_type	Number
	crane_cap	Number
	hook_height	Number
	door_height	Number
	door_width	Number
	additional_notes	Short Text

The PROJECTS table contains specifics on each project.

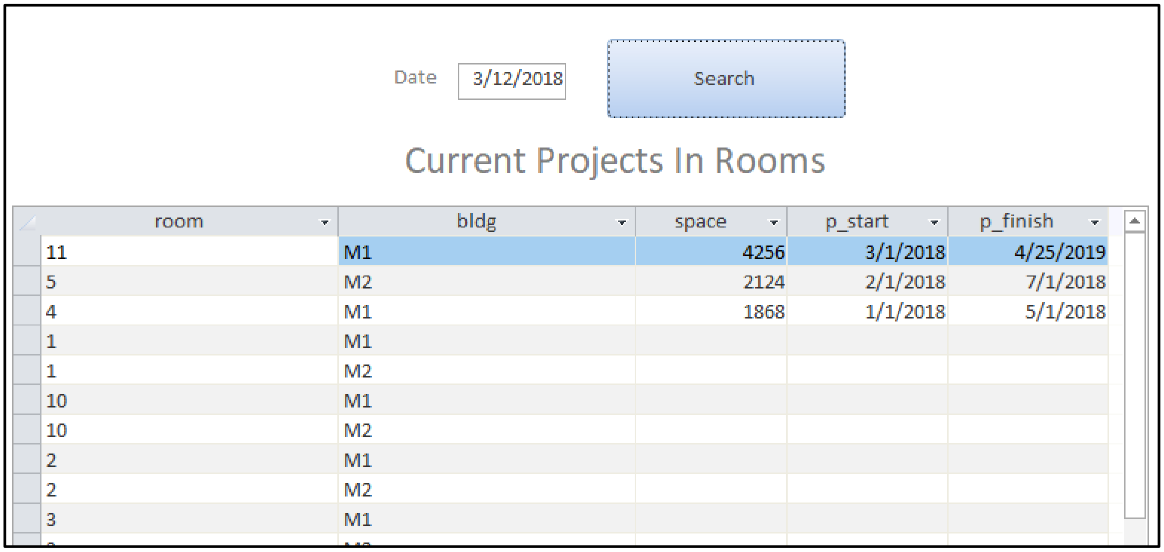
As you can see from the snapshots, the primary keys have been placed on “proj”, “subproj”, “room”, and “bldg”. All four of these primary keys are linked through the ASSIGNMENTS table as foreign keys to show what project is in which room at any time. A project can be unassigned to a room, which would make it a proposed project before a lab manager has officially assigned it. This also allows for easily adding projects and rooms, which makes this design flexible and expandable.



	Field Name	Data Type
🔑	proj	Short Text
🔑	subproj	Short Text
	pme	Short Text
	part_name	Short Text
	qty	Short Text
	sq_ft	Number
	height	Short Text
	control_room	Short Text

From these three tables, we have begun creating user interfaces using forms to generate multiple views. We would like the user to be able to search and rank rooms, visually see how much space and which projects are in each room at any given time, add rooms and projects, assign projects to rooms, and update rooms, project, and assignment parameters.

So far, we have developed a view to see the space available in a room at any given date using the square footage that all the projects take up in a room subtracted by the available square footage in a room.

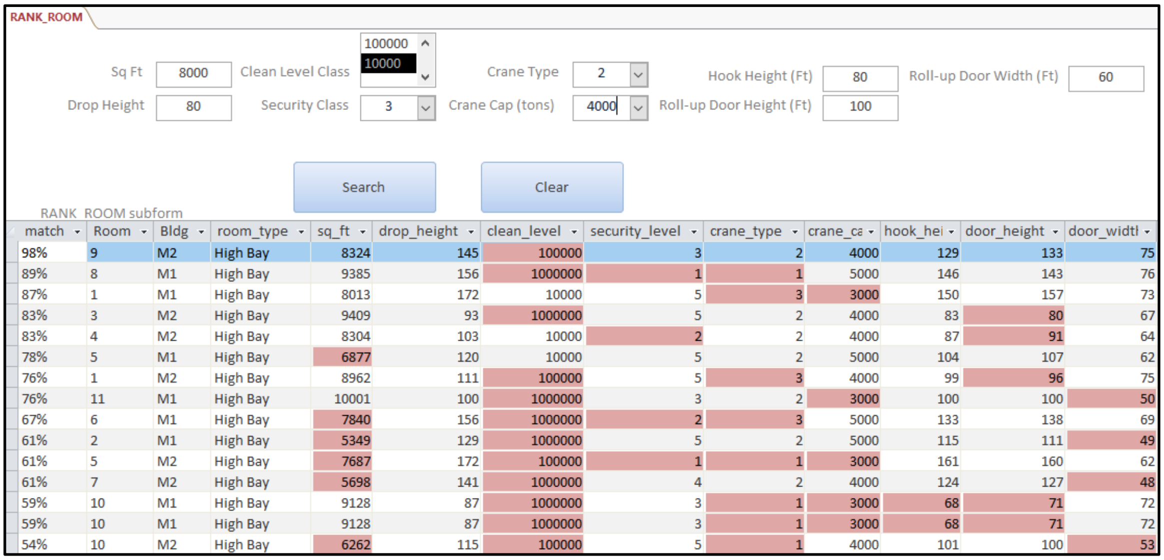


Date 3/12/2018

Current Projects In Rooms

room	bldg	space	p_start	p_finish
11	M1	4256	3/1/2018	4/25/2019
5	M2	2124	2/1/2018	7/1/2018
4	M1	1868	1/1/2018	5/1/2018
1	M1			
1	M2			
10	M1			
10	M2			
2	M1			
2	M2			
3	M1			

Next, we also created a room search form where you enter desired parameters for each room. The parameters that do not match are highlighted red and moved to the bottom. The percentage match functionality was preferred over eliminating rooms that don't work by the company that we are working with. As you can see from the screenshot below, none of the rooms match the desired criteria. However, due to another table that we created called "WEIGHTS" that holds values for each criteria weight, Room 9 in Building 2 is a 98% match, and the only upgrade that is required is a clean room upgrade, which is much easier than a square footage upgrade.



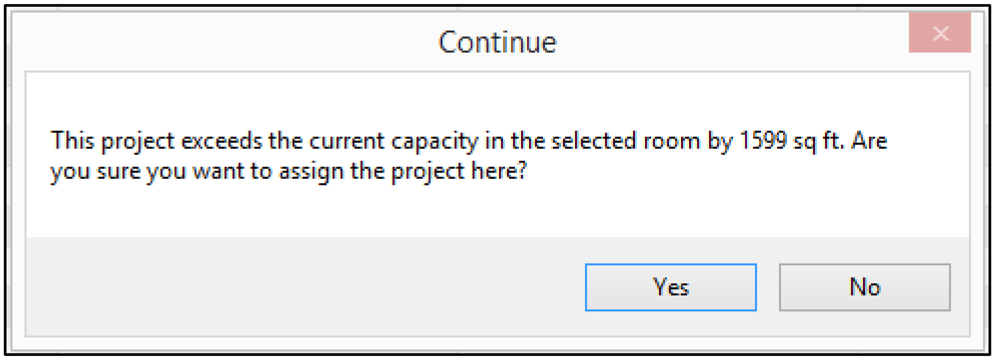
Sq Ft 8000
Clean Level Class 100000 / 10000
Crane Type 2
Hook Height (Ft) 80
Roll-up Door Width (Ft) 60
Drop Height 80
Security Class 3
Crane Cap (tons) 4000
Roll-up Door Height (Ft) 100

match	Room	Bldg	room_type	sq_ft	drop_height	clean_level	security_level	crane_type	crane_ca	hook_hei	door_height	door_widtl
98%	9	M2	High Bay	8324	145	100000	3	2	4000	129	133	75
89%	8	M1	High Bay	9385	156	1000000	1	1	5000	146	143	76
87%	1	M1	High Bay	8013	172	10000	5	3	3000	150	157	73
83%	3	M2	High Bay	9409	93	1000000	5	2	4000	83	80	67
83%	4	M2	High Bay	8304	103	10000	2	2	4000	87	91	64
78%	5	M1	High Bay	6877	120	10000	5	2	5000	104	107	62
76%	1	M2	High Bay	8962	111	100000	5	3	4000	99	96	75
76%	11	M1	High Bay	10001	100	1000000	3	2	3000	100	100	50
67%	6	M1	High Bay	7840	156	1000000	2	3	5000	133	138	69
61%	2	M1	High Bay	5349	129	1000000	5	2	5000	115	111	49
61%	5	M2	High Bay	7687	172	100000	1	1	3000	161	160	62
61%	7	M2	High Bay	5698	141	1000000	4	2	4000	124	127	48
59%	10	M1	High Bay	9128	87	1000000	3	1	3000	68	71	72
59%	10	M1	High Bay	9128	87	1000000	3	1	3000	68	71	72
54%	10	M2	High Bay	6262	115	100000	5	1	4000	101	100	53

IV. Methodology

The approach to testing was to create the desired function in Access and then attempt to break it or get undesired results. The design was tested using false numbers relating to high bay and project specifications (actual numbers were not available). The different functions of the database (create project, edit/delete project, search high bays, etc.) were tested in a variety of ways to ensure the system properly worked.

An example of this is scheduling rooms in high bays. Each high bay only has a certain number of square feet available to hold projects. Should a project be scheduled in a high bay already at capacity a pop-up window appears warning the user that the room is ‘x’ amount of square feet over capacity. It also offers options to either ignore the warning and schedule the project anyways or to go back to the form and select another room. Different combinations of projects and rooms were used to determine if the system was working as it should.



This project exceeds the current capacity in the selected room by 1599 sq ft. Are you sure you want to assign the project here?

Under this approach, a multitude of errors were discovered relating to when users neglected to fill out all fields in a form or used improper formatting for answers. Although not conducted with real numbers provided by Northrop Grumman, it is reasonable to believe that the success of the system using false data will translate directly into successful operation using proprietary data.

V. Results

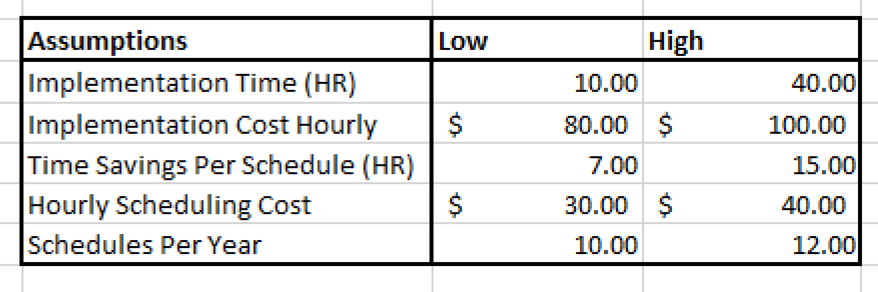
The results were exactly as expected. Because the database was built from the ground up the functions, and their limitations, were known well in advance. The theory (database design) behind the project held true to itself and allowed the creation of a unique system capable of tracking multiple projects in multiple rooms at the same time.

In terms of user-friendliness, the design is very simple and easy to use. Thus, new users should have no problem becoming familiar with it and integrating it into their current arsenal of tools at Northrop Grumman. However, when it comes to making updates to the system, the design is lacking. In order to make any changes or additions to project or high bay attributes it is necessary to edit tables, queries (which can be very long and complicated to understand), forms/subforms, and VBA code.

With respect to productivity, this tool is expected to dramatically cut down the time necessary to locate a suitable high bay from a period of up to several weeks down to as little as 10-15 minutes. This is due to the centralization of information related to high bays and scheduled projects. Before, this information was scattered around the facility (or simply no known) and had to be hunted down before a scheduling decision could be made.

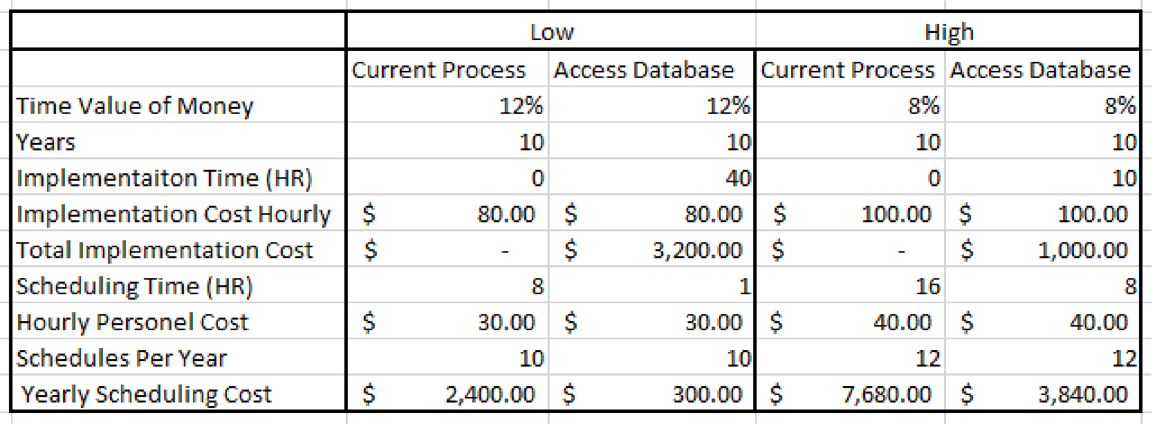
Economic Analysis

To understand the financial effects of our project, we conducted a cost analysis. To calculate the benefits of the new system, we estimated the cost of scheduling a project, and multiplied it by the scheduler's salary and number of projects per year. Two scenarios were developed, one being a minimum (low) expected cost, and one being a maximum (high). A number of assumptions were made:



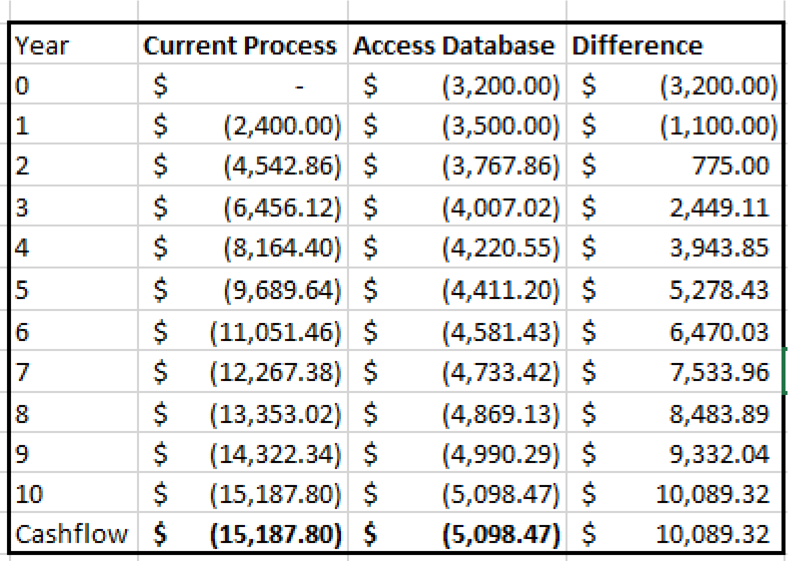
Assumptions	**Low**	**High**
Implementation Time (HR)	10.00	40.00
Implementation Cost Hourly	$ 80.00	$ 100.00
Time Savings Per Schedule (HR)	7.00	15.00
Hourly Scheduling Cost	$ 30.00	$ 40.00
Schedules Per Year	10.00	12.00

First, we assumed that training employees to use our system would take between 10 and 40 hours, and that the training cost would be between $80 and $100 per hour. Next, we estimated the time savings of using our system over the current system to be 7-15 hours per schedule. Finally, a scheduling salary of around $70,000 per year would mean an hourly scheduling cost of $30-$40, and we estimated 10-12 schedules per year.



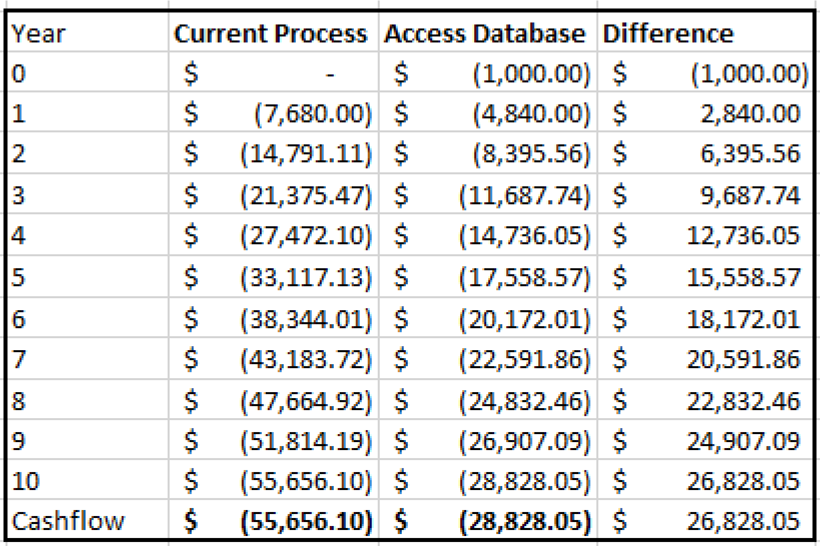
	Low		High	
	Current Process	Access Database	Current Process	Access Database
Time Value of Money	12%	12%	8%	8%
Years	10	10	10	10
Implementaiton Time (HR)	0	40	0	10
Implementation Cost Hourly	$ 80.00	$ 80.00	$ 100.00	$ 100.00
Total Implementation Cost	$ -	$ 3,200.00	$ -	$ 1,000.00
Scheduling Time (HR)	8	1	16	8
Hourly Personel Cost	$ 30.00	$ 30.00	$ 40.00	$ 40.00
Schedules Per Year	10	10	12	12
Yearly Scheduling Cost	$ 2,400.00	$ 300.00	$ 7,680.00	$ 3,840.00

Based off of these assumptions, we calculated the implementation cost of our system to be between $1,000 and $3,200. The yearly cost of scheduling with the current system was estimated between $2,400 and $7,680, while our Access database would cost between $300 and $3,840 yearly.



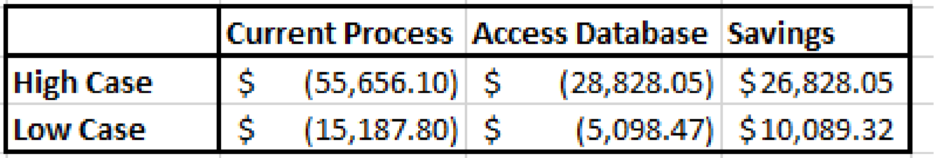
Year	**Current Process**	**Access Database**	**Difference**
0	$ -	$ (3,200.00)	$ (3,200.00)
1	$ (2,400.00)	$ (3,500.00)	$ (1,100.00)
2	$ (4,542.86)	$ (3,767.86)	$ 775.00
3	$ (6,456.12)	$ (4,007.02)	$ 2,449.11
4	$ (8,164.40)	$ (4,220.55)	$ 3,943.85
5	$ (9,689.64)	$ (4,411.20)	$ 5,278.43
6	$ (11,051.46)	$ (4,581.43)	$ 6,470.03
7	$ (12,267.38)	$ (4,733.42)	$ 7,533.96
8	$ (13,353.02)	$ (4,869.13)	$ 8,483.89
9	$ (14,322.34)	$ (4,990.29)	$ 9,332.04
10	$ (15,187.80)	$ (5,098.47)	$ 10,089.32
Cashflow	**$ (15,187.80)**	**$ (5,098.47)**	$ 10,089.32

In the minimum (low) case, the current process would cost $15,000 over 10 years, while the Access database would cost $5,000. This would result in a net savings of $10,089 over 10 years.



Year	Current Process	Access Database	Difference
0	$ -	$ (1,000.00)	$ (1,000.00)
1	$ (7,680.00)	$ (4,840.00)	$ 2,840.00
2	$ (14,791.11)	$ (8,395.56)	$ 6,395.56
3	$ (21,375.47)	$ (11,687.74)	$ 9,687.74
4	$ (27,472.10)	$ (14,736.05)	$ 12,736.05
5	$ (33,117.13)	$ (17,558.57)	$ 15,558.57
6	$ (38,344.01)	$ (20,172.01)	$ 18,172.01
7	$ (43,183.72)	$ (22,591.86)	$ 20,591.86
8	$ (47,664.92)	$ (24,832.46)	$ 22,832.46
9	$ (51,814.19)	$ (26,907.09)	$ 24,907.09
10	$ (55,656.10)	$ (28,828.05)	$ 26,828.05
Cashflow	**$ (55,656.10)**	**$ (28,828.05)**	$ 26,828.05

In the maximum (high) case, the current process would cost $55,000, and the Access database would cost $28,000. This results in a savings of $26,828 over a 10 year period.



	Current Process	Access Database	Savings
High Case	$ (55,656.10)	$ (28,828.05)	$ 26,828.05
Low Case	$ (15,187.80)	$ (5,098.47)	$ 10,089.32

Graphing the difference in cash flow over time, we find that the Access database would save $26,828 at maximum, and $10,089 at a minimum.

VI. Conclusion

Our project focused on the inefficiency of the current process scheduling process. Our objectives were to create a faster way of scheduling projects, and a visual representation of the current capacity and utilization. To create our prototypes we collected all information on the attributes and requirements for each high bay and project, and organized them in an efficient and standardized manner. The final Access prototype was a database that tracked utilization at any time, and has the ability to schedule and edit current projects.

Based on the results mentioned above, the design could be improved by incorporating the actual project and highbay parameters from the start. Changes to the tool are tedious and difficult to make - it would have been far better to not need to make changes in the first place. Additional features that would be useful are security screening and admin privileges. Security screening refers to the level of detail on certain projects that users can see based on their security clearance. For example, a user with a lower clearance than Project X is rated for would simply see that there is a project scheduled for a highbay without actually knowing the name or parameters of the project. Admin privileges would be given to higher ranking employees with the power to edit projects/highbays and make scheduling decisions. The other features (room/project search, etc.) would still be available to other users, but only those with admin privileges would be able to make changes to the tool.

Overall, we came up with three main conclusions:

- Projects requirements and room attributes should be saved in an organized, standard format
- Updates to this schedule should be changed instantaneously and visible to all employees deemed necessary
- Admin privileges and security clearances require different levels of visibility for each employee

Through this project we did accomplish our goals of developing a standardized system. We also improved the efficiency of scheduling each project and estimated a savings between $10,000 and $25,000 over 10 years. If we were to further research this topic, we would focus more time on user interface and the ease of using our system.

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