SYS625 -- System Operational Effectiveness and Life Cycle Analysis
Sample Project

QUESTION:

Define a deficiency (operational, functional, or cost-related), need, or a market/product opportunity. *It is recommended that this project be related to the goals of your sponsoring organization*. Analyze this need to define and classify a set of stakeholder requirements. *These* stakeholders *should be "real." Please submit any documentation resulting from interviewing these customers*. In order to formulate the customer requirements completely, the following constructs will have to be developed:

a) List of stakeholders (both, active and passive), along with a clear understanding of the primary customer(s).
b) List of stakeholder requirements and/or constraints for each
c) List of the system concepts considered and the selection of a preferred concept (through the application of Pugh's Concept Selection Matrix).
d) Development of a system context diagram, and an understanding of the system boundary and scope.

Translate the above into a set of system requirements through the application of the following constructs:
a) The translation of stakeholder requirements into system requirements (largely non-functional) through the application of Quality Function Deployment
b) The development of use case scenarios to understand the system behavior and functional requirements
c) In order to facilitate this process, also develop a set of requirement categories to focus your activities. Are there any strategic non-functional requirements that you will focus on during the development process (e.g., safety is always a priority for VOLVO cars)?

The above process is not viewed as a sequential and linear process, but rather as a highly iterative (often chaotic) set of activities with subsequent decisions providing more insight into the earlier steps in the synthesis process.

Attempt to document this thought process during the course of your case study development. Also document any trade studies or assumptions that you make.

After formulating the system requirements, develop the first level functional architecture for your system, and ensure functional completeness by tracing two of your more significant use cases through this functional architecture.

RESPONSE:

Deficiency, Need or Market Opportunity

The deficiency I intend to address is the lack of a single, integrated software-based system that will perform all of the functions necessary within the manufacturing environment at Surface Systems in Moorestown, New Jersey. This system would be designed such that it could also be used at other sites, if so desired, with few changes.

Surface Systems has a large manufacturing base that produces thousands of individual assemblies from hundreds of thousand of procured materials. PIOS, the Production and Inventory Optimization System, is a material requirements planning system used to control all facets of this material with regard to production, but is far from optimal in its functionality.

The most significant deficiency of the PIOS system is that is was designed around a "push" production control methodology, which is in direct conflict to the corporation's growing migration toward a Lean "pull" methodology. A "push" methodology is based on the promise that subassemblies will be built despite the fact that the next higher assembly is not ready to use them, while a "pull" system receives its queue from the next higher assembly in just enough time for the subassembly to be assembled, reducing cycle time and inventory costs.

The DOS-based PIOS software and infrastructure, written and designed over a decade ago, has become increasingly difficult to maintain, as the code for the program grows antiquated and personnel with this experience grow scarce.

PIOS also does not perform any other critical strategic functions necessary in manufacturing, such as labor charging, labor reporting, assembly rate management, cost and earned value management, purchasing, inventory management, assembly defect/reject management and access to digital drawings and processes. Other independent software platforms are used for each of these functions. Some have been manually linked to PIOS, which is difficult to do with questionable results, but most cannot be linked. Some necessary functions do not even have a system, such as manpower and long range business planning. Various individuals perform these functions, each with their own methods. These methods generally include the manual manipulation of data from hard-copied information using desktop computer applications.

Identification of Stakeholders

The primary customer for the new system will be the Surface Systems business in Moorestown, New Jersey. The customer can also be extended to include other sites within the corporation, as the system will be made available to all sites. The "bill-paying" customer will ultimately be the Vice President of Production & Life Cycle Programs, but this individual will base decisions on the advice of the functional Directors whose groups will ultimately be using this system. These active stakeholders are the Directors of Operations, Materials, Program Management and Master Scheduling. Other active stakeholders include production control analysts, production supervisors, production floor personnel, inventory control personnel, master scheduling personnel, the program management organization, commodity planners, component engineers, finance analysts, the information technology support team, purchasing and expediting agents, business systems integrators, the quality organization and managers of all stakeholders. Non-human active stakeholders include the Internet, mainframe devices, Exostar (web-based purchasing system), personal desktop computers and printers. These are all individuals and systems that will actively interact with the system once it is operational.

All customers of Surface Systems' (and potentially all sites within the corporation) products and services serve as passive stakeholders. They include the U.S. Navy, Navies of several international countries, and other global businesses for whom Surface Systems supplies products and services. Additional passive stakeholders are the Corporate Management Team and Government purchasing guidelines.

Customer and Stakeholder Requirements

In order to accurately determine the customers' requirements for the system, I conducted several inquiries and interviews, asking specific questions about the desired functionality of the system and deficiencies of the current system. Essentially, I was trying to tailor my questions such that I would learn what these individuals felt would be their "dream" system.

Capturing the voice of the customer objectively without introducing any bias from my personal experience of the subject matter or my experience with those interviewed was a chaotic, iterative process. It was difficult to keep my mind from gravitating toward system requirements before accurately capturing the customer's requirements. I tried to combat this by using several techniques in my interviewing process. I asked general and vague question, while encouraging the individuals to include both voice and image, then I asked probing questions and reviewed my notes.

Those interviewed consisted of two Production Control Managers, the Director of Production Operations, the Director of Materials and Depot Operations, a Production Operations Manager, the Manager of Commodity Planning, a Commodity Planner, the Manager of Materials Control, two Business Systems Applications Analysts, four Production Control Analysts and the Master Scheduler.

Some examples of the customer voice received are:

> "This system would be more designed on a Lean (pull) system versus MRP (push) system. Kanban and visual controls would be the preferred method of production. The computer system could monitor your WIP progress on colored charts, so you could view from home at any time of the day. This would require a very flexible workforce and creative process flow. The system would use a backflush or post deduct (reduce inventory based on completing assembly) inventory stem to reduce some of the unnecessary inventory management controls. A paperless system would probably yield some benefits. The system should complement the type of product that is being produced such as process or discrete component industry. Some deficiencies with the current system are the untimely disposition that is a critical driver in a time phased MRP system. Also, there are too many functions involved with the current system. Look at eliminating the roadblocks in PIOS and determining why they were put in place."
>
> - Manager (1), Production Control

> I would really like to see PIOS, MES, CPS and SQS replaced with one material system – totally integrated. Nightly MRP runs, as opposed to weekly. You would get order signals daily, instead of weekly. This would expedite the ordering for ECN cut-in's, scraps, etc. If there was one material system, you would eliminate disconnects between the many systems. Today we have situations where CPS shows an order closed, PIOS still shows it open, CPS has one revision level, and PIOS has another. Material gets scrapped in SQS, but at times it doesn't flow to PIOS. Also, it would be great to have a system that would do full capacity planning instead of just attempting to level load the schedules."
>
> - Manager, Commodity Planning

> "A shorter MRP run…nightly vs. weekly. Some capacity planning capability. Report software from MRS vs. EIS programming or datawarehouse. Better firm-planning or scheduling at the sub-assembly levels in PIOS. Better help tutorials especially for those who want to put down the system vs. understand it first. Much of the system, especially MES, goes unutilized. More user friendly windows type application."
>
> - Manager (2), Production Control

"PIOS has several issues that…have to do with the system being an aging legacy system built on old technology and the fact that it does not integrate will with the newer systems. Additionally we would like to improve functionality: 1) PIOS simulation capability to be more responsive with "what if" analysis for planning; 2) Improve system functionality to allow PIOS to handle makes and buys for the same part number in the same plant code; 3) Support new business type issues with commercial and international programs with contractual requirements that limit our ability to commingle, forcing separate plant codes in PIOS."

- Manager, Business Systems Application

As a result of the interviewing and data sorting process, I have determined the stakeholder requirements to be those listed in Figure 1. They detail the customer's need for a managed cost system with specific functional capabilities, not limited to production control, which is maintainable, reliable and easy to use. Key performance parameters have been determined to include system cost, "pull" system, production control, performance and ease of use.

Stakeholder Requirements	Includes:
Assembly Process Control	
	Assign work orders Display electronic drawings Labor rate management Sequential indication Work order control
Capacity planning	
	Capacity planning
Ease of Use	
	Easy to read screen High processing speed Limited steps for changes Place-saving Provide remote access User instructions
Forecasting	
	Forecasting Simulations capabilities
Integrated Sub-Systems	
	Integrated sub-systems Interplant capability
"Pull System"	
	"Pull" system Utilize Kanbans
Labor Charging	
	Labor rate management Time management
Maintainability	
	Maintainability
Manpower Planning	
	Manpower planning
Performance	
	Data recording Information inquiries Real time updates Standard date format

Blue denotes key performance parameter

Stakeholder Requirements	Includes:
Production Control	
	Build schedule Configuration control Control reorder points Establish discrete part numbers Firm plan orders Issue production plans Level load production Monitor cycle time Monitor schedule performance Non-duplication Order control Prioritize requirements Provide part identifiers Provide production status Reserve parts/assemblies Serialization Smart scheduling
Project Cost Analysis	
	Manage project cost
Purchasing / Material Control	
	Control material availability Create manual material orders
Quality Management	
	Defect management Quality dispositions
Reliability	
	Reliability
Reports	
	Print reports
Security	
	Controlled access
System Cost	
	Low maintenance costs Low operating costs Low purchase costs
Inventory Management	
	Inventory management

Figure 1, Stakeholder Requirements

Concept Selection

Once the customer's requirements had been established, three concepts were generated to satisfy those requirements. These concepts were the "PIOS Link", the "Web MMS" and the "Standing MMS".

The "PIOS Link" concept entails augmenting the existing legacy PIOS system to satisfy the additional needs of the customer. Thus, existing code in PIOS would be re-written to address those functions that are required that PIOS is in direct contract with, such as the "pull" methodology and real-time updates, while new code would be written into the software to address those requirements that do not exist today, such as manpower and capacity planning capabilities.

The "Web MMS" concept, or web-based Manufacturing Management System, would be a newly designed software system whose code would be written specifically to address the customer requirements. Furthermore, it would be designed around accessibility from the Internet. The "Standing MMS" concept also consists of a new system, however, rather than being designed for Internet access, this system would be "stand-alone", meaning that the software would have to be loaded onto specific desktop computers or company mainframes for access.

	Concept 1 "PIOS Link"	Concept 2 "Web MMS"	Concept 3 "Standing MMS"
Assembly Process Control	s	+	+
Capacity planning	-	+	+
Project Cost Analysis	s	+	+
Ease of Use	-	+	+
Forecasting	-	s	s
Integrated Sub-Systems	-	+	+
Inventory Management	+	+	+
Labor Charging	+	+	+
Maintainability	-	+	s
Manpower Planning	-	+	+
Performance	-	+	+
Production Control	+	+	+
"Pull System"	-	s	s
Purchasing / Material Control	+	+	s
Quality Management	+	+	+
Reliability	s	+	+
Reports	s	+	+
Security	s	s	+
System Cost	s	+	-
Σ +	5	16	14
Σ –	8	0	1
Σ s	6	3	4

Blue denotes key performance parameter

Figure 2, Stakeholder Requirements

In order to objectively determine the system that best addresses the stakeholders' requirements, a Pugh Concept Selection Matrix was used, as shown in Figure 2. By individually comparing each concept's performance against each stakeholder requirement and then aggregately summing those comparisons, the Pugh Matrix provides the systems engineer the ability to determine which concept most completely addresses the stakeholders' requirements. In this case, the Pugh Matrix has determined that the "Web MMS" is the preferred concept.

The "PIOS Link" concept was the least capable of satisfying the requirements. While purchasing costs of the system are mitigated as a result of building upon an existing system, the operating and maintenance costs will be high based on the obsolescence of the PIOS software code, resulting in a neutral effect on system cost. The "PIOS Link" is anticipated to have lower the required performance in nearly half of the stakeholders' requirements, including three out of five of the key performance parameters.

The "Web MMS" and "Standing MMS" concepts were evidenced by the Pugh Matrix to be nearly identical in their respective ability to satisfy or improve upon the stakeholders' requirements, but by analyzing the individual performance by requirement, it shows that the "Standing MMS" performs poorer than the "Web MMS" in several categories, including one of the key performance parameters, cost. The "Web MMS" will be less costly to maintain and operate as a result of its Web accessibility feature. This will also improve its purchasing ability, providing better accessibility to the web-based purchasing system, Exostar. While the company and personal computer specific nature of the "Standing MMS" provides better performance in the security category than the "Web MMS", this was not sufficient to warrant selection of that concept.

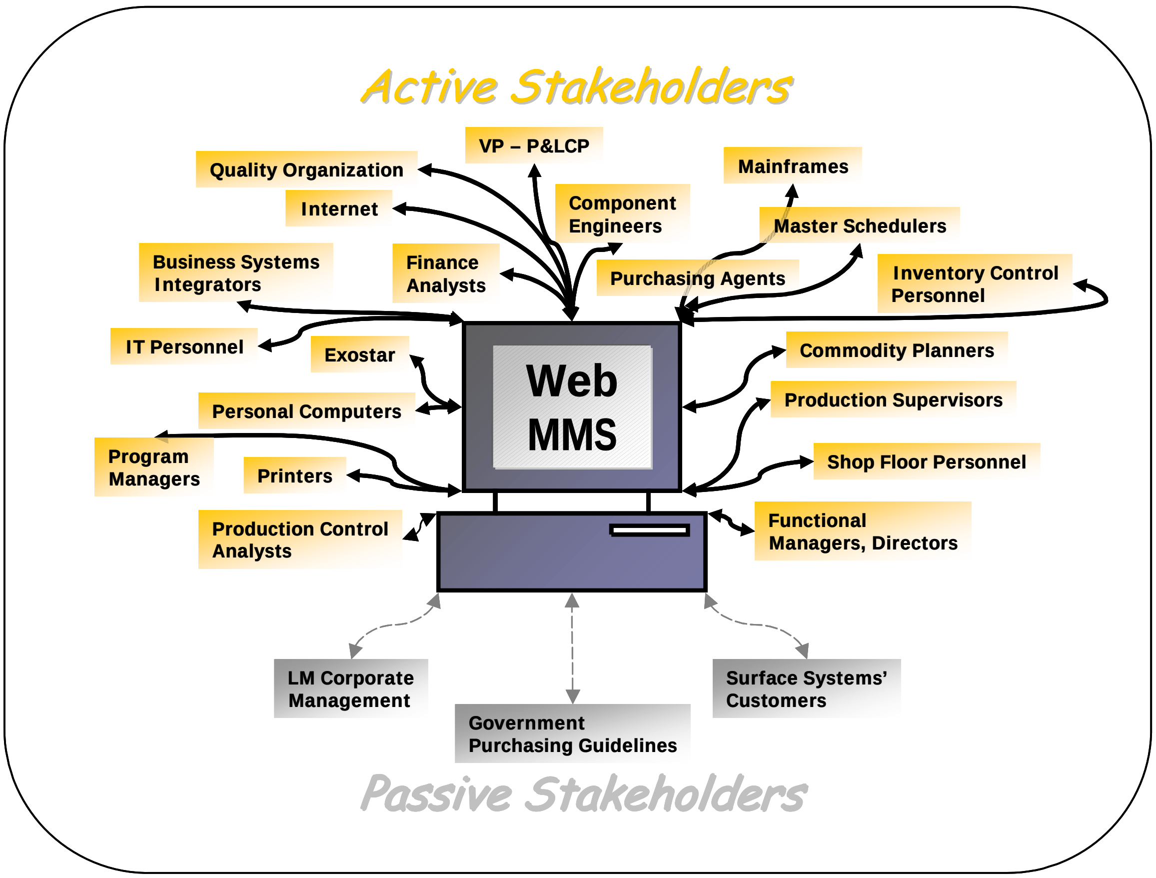


Figure 3, System Context Diagram

System Boundary and Scope

The system context diagram in Figure 3 visually depicts the boundary and scope of the "Web MMS". As the "Web MMS" is a software specific solution to the customer requirements, it is intuitive that its scope consists of data transfer between the system and its active stakeholders, whether in the form of screen-based interactions or hard-copied reports. Conversely, the passive stakeholders will impact, but not be impacted by the system.

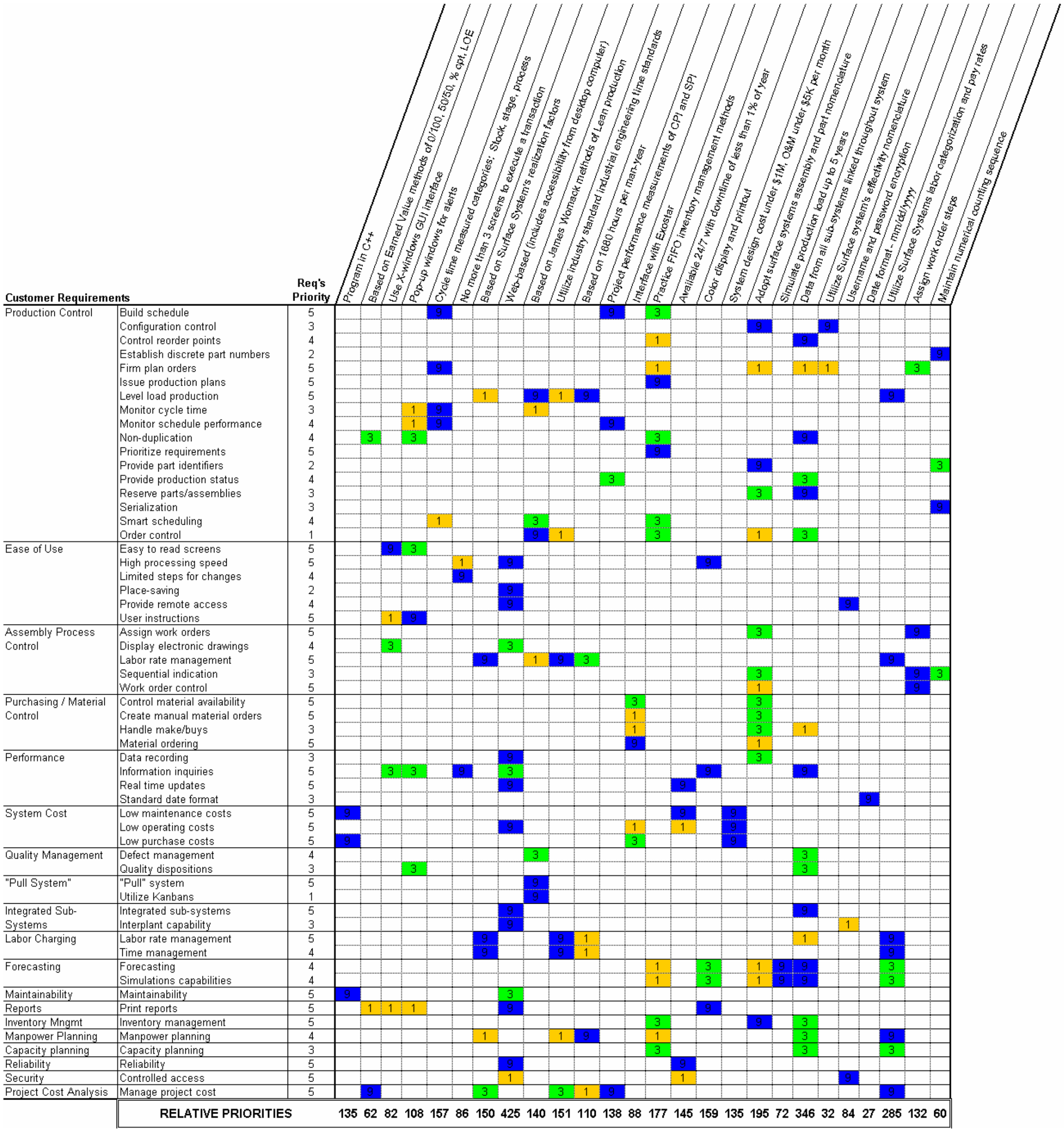


Figure 4, Quality Function Deployment

Determination of Non-Functional, or System-Wide Requirements

Once the stakeholders and their requirements have been identified, concepts down-selected based on those requirements and system scope determined, a set of non-functional or system-side requirements can be established.

The system-wide requirements represent those guidelines that apply at the system level. They are largely non-functional, which is to say that they will not result in a performed function, but rather will represent a measurement of adherence to stakeholder requirements. Examples are graphical user interface type and cost parameters. The Quality Function Deployment tool, or QFD, shown in Figure 4, is used to establish these requirements. By using this visual tool, the system engineer is ensured to translate each stakeholder requirement, listed on the left-most column of the matrix, into a system-wide requirement, listed along the top row, which will be maintained through the systems engineering and design processes. Numerical correlations between the stakeholder and system-wide requirements are then applied. If a row remains empty, or has no correlation, then the systems engineer has not established a system-wide requirement that will address the respective stakeholder requirement. Similarly, all columns must contain a numerical correlation in order to avoid unnecessary design effort. Empty columns indicate that a system-wide requirement does not trace to a stakeholder requirement, thus is unnecessary. When correlations are mathematically compared to assigned priorities of stakeholder requirements, the relative priority of each system wide requirement is established. The relative priority allows the systems engineer to focus on the most significant system-wide requirements. In the "Web MMS" QFD, all stakeholder requirements have been addressed and all system-wide requirements are pertinent, as evidenced by no empty rows or columns. Additionally, strategic system-wide requirements have been identified by high relative priority: Web-based, integrated sub-systems, labor categorization/pay rates and assembly/part nomenclature.

Inherently, checking for empty rows and columns represents the iterative nature of the QFD/system-wide requirements establishment process. After the "Web MMS" QFD was initially created, empty rows and columns were found, which had to be addressed. This forced me to refer back to stakeholders' requirements and clarify based on system-wide requirements that surfaced with no existing stakeholder requirements with which to correlate.

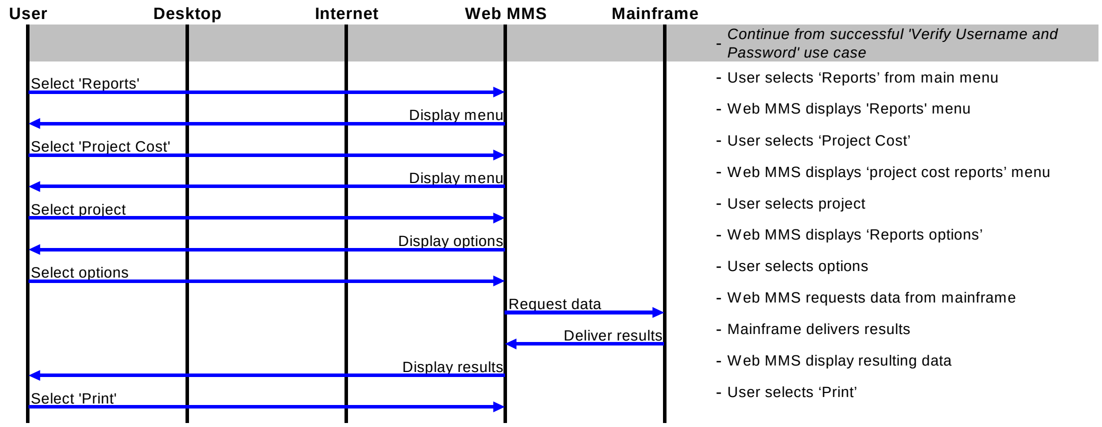
Determination of Functional Requirements

To understand the system behavior and ultimately determine the functional requirements, five use case scenarios were established. Three of these use case scenarios are detailed in Figure 5, while the remaining two are used in the 'First Level Functional Architecture' discussion to verify functional completeness by tracing the use cases through the architecture.

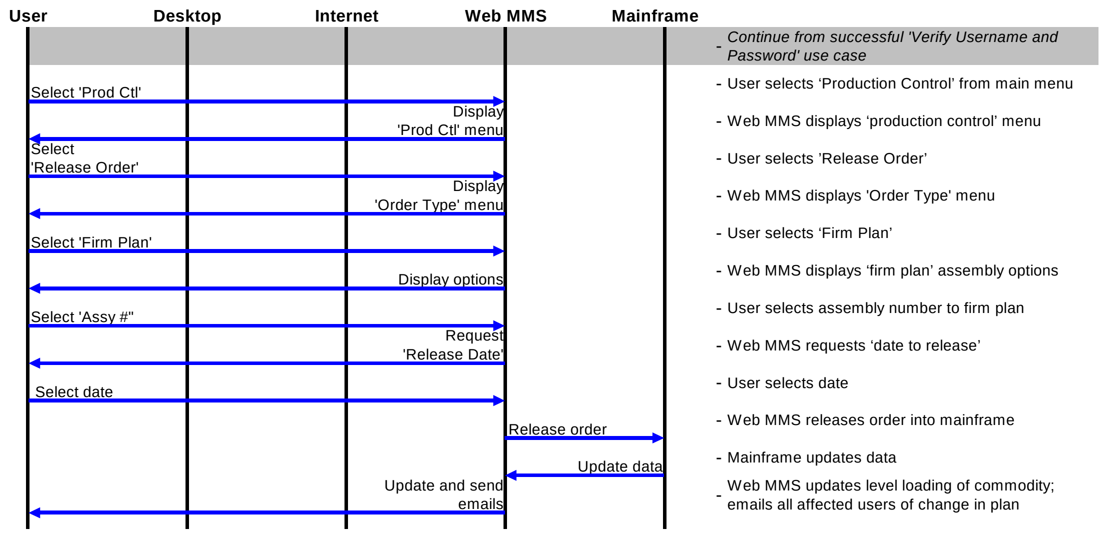
During this process, I had to revisit my list of stakeholders and associated requirements. The use case scenarios pointed out that once I had determined the concept of choice to be the "Web MMS", it resulted in the addition of the Internet as a stakeholder and subsequently identify any requirements that this stakeholder might have.

The use case scenarios were a very important step in the systems engineering process of the Web MMS project. In particular, the use cases pointed out that the data input from the human user had to pass through two external systems in order to reach the Web MMS, namely the desktop computer and the Internet. This fact is taken for granted due to our regular use of the Internet and the "second nature" of accessing it, but is not intuitive in the systems engineering process until the application of use case scenarios.

Print a Project Cost Report



Release a Firm-Planned Order



Establish a Manpower Plan for a Work Area

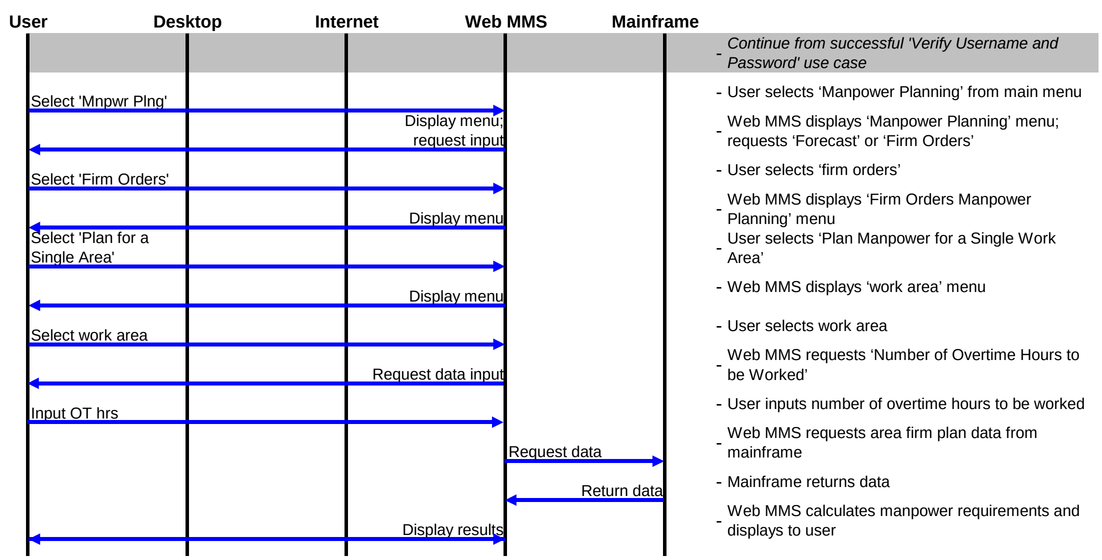


Figure 5, Use Case Scenarios

Categorized Web MMS System Requirements

The requirements resulting from the Quality Function Deployment and use-case scenarios for the Web MMS have been cumulated and placed into a set of Operational Phase requirement categories in order to focus the systems engineering process at the subsequent phases. They are as follows:

1.0 OPERATIONAL PHASE REQUIREMENTS

1.1 Functional Requirements

1.1.1 The system shall provide access to an authorized user
1.1.2 The system shall accept customer inputs and provide feedback
1.1.3 The system shall calculate/establish responses to inputs received
1.1.4 The system shall communicate with and store data in the mainframe computer
1.1.5 The system shall provide a maintenance mode

1.2 Input/Output Requirements

1.2.1 Input Requirements

1.2.1.1 The system shall accept a Internet web address for access
1.2.1.2 The system shall accept a login request
1.2.1.3 The system shall accept inputs from the Internet
1.2.1.4 The system shall accept inputs and requests from the user
1.2.1.5 The system shall accept username and password identification from the user
1.2.1.6 The system shall accept data from the mainframe
1.2.1.7 The system shall accept username and password entry results from mainframe

1.2.2 Output Requirements

1.2.2.1 The system shall provide the Web MMS home page
1.2.2.2 The system shall provide reports to a printer or desktop computer screen
1.2.2.3 The system shall provide a main menu specific to the credentials of the user
1.2.2.4 The system shall provide a request for username and password
1.2.2.5 The system shall provide a request for username and password verification from the mainframe
1.2.2.6 The system shall provide a request data from the mainframe
1.2.2.7 The system shall provide menus and displays specific to each informational category within the system (capacity planning, simulation, production control, manpower planning, etc.)
1.2.2.8 The system shall provide requests for inputs or options specific to each informational category within the system (capacity planning, simulation, production control, manpower planning, etc.)

1.3 System-Wide (Non-Functional) Requirements

1.3.1 Ease of Use

1.3.1.1 The Web MMS shall use X-Windows graphical user interface
1.3.1.2 The Web MMS shall use pop-up windows for alerts
1.3.1.3 The Web MMS shall execute changes in 3 screens or less
1.3.1.4 The Web MMS shall be accessed from the Internet

1.3.2 *Reliability/Maintainability*

1.3.2.1 The Web MMS shall have a downtime no greater than 1% per year

1.3.2.2 The Web MMS shall be accessible 24 hours per day, 7 days per week
1.3.2.3 The Web MMS shall be programmed using C++

1.3.3 Cost
1.3.3.1 The Web MMS design cost shall be $1M or less
1.3.3.2 The Web MMS operations and maintenance cost shall be $5K per month or less

1.3.4 Security
1.3.4.1 The Web MMS shall maintain 8-digit username and password encryption

1.3.5 Performance
1.3.5.1 The Web MMS shall use the mm/dd/yyyy date format
1.3.5.2 The Web MMS shall have a color display and provide color, graphical printout
1.3.5.3 The Web MMS shall be accessed from a desktop computer

1.3.6 *System Services*
1.3.6.1 The Web MMS shall use Earned Value methodology of 0/100, 50/50, percent complete and Level of Effort
1.3.6.2 The Web MMS shall measure cycle time in stock, stage and process categories
1.3.6.3 The Web MMS shall apply industrial engineering realization factors based on Surface System's methods
1.3.6.4 The Web MMS shall be based on James Womack methods of Lean production
1.3.6.5 The Web MMS shall utilize industry standard industrial engineering time standards
1.3.6.6 The Web MMS shall base manpower calculations on 1,680 hours per man-year
1.3.6.7 The Web MMS shall base project performance measurements on cost and schedule performance indices (CPI and SPI)
1.3.6.8 The Web MMS shall interface with the web-based purchasing system, Exostar
1.3.6.9 The Web MMS shall manage inventory based on first-in-first-out (FIFO) methodology
1.3.6.10 The Web MMS shall use assembly and part nomenclature consistent with Surface Systems
1.3.6.11 The Web MMS shall be capable of providing 5-year production load simulations
1.3.6.12 The Web MMS shall link data from all sub-systems (capacity planning, manpower, production, etc.) throughout system
1.3.6.13 The Web MMS shall use effectivity nomenclature consistent with Surface Systems
1.3.6.14 The Web MMS shall use labor categorization and pay rates consistent with Surface Systems
1.3.6.15 The Web MMS shall establish work order steps within assemblies consistent with Surface Systems
1.3.6.16 The Web MMS shall maintain numerical counting sequences

The 'System Services' category will be the requirement category of primary focus during the development process. 'System Services' represents such services as capacity and manpower planning, quality management, production control, forecasting, etc. that have been discussed regularly throughout this process. These categories are also those that were identified as having the highest relative priority in the Quality Function Deployment and were identified by the customer as having major significance in the original interviews.

The establishment of the system requirements, in particular the functional and input/output requirements of the system, became yet again a highly iterative process once the functional architecture was established. I would revert back to the requirements regularly as the architecture was created, noticing that there had been several missed or incorrectly written requirements. After correcting the requirements, I would correct the architecture based on new insights that the corrected requirements uncovered. In the end, these iterations gave me significant confidence that the architecture was complete. This would be further tested and confirmed, with yet another iterative process, in the tracing of the use case scenarios in the next discussion.

First Level Functional Architecture

At this point, the necessary background information has been established in order to proceed with the first level functional architecture, as shown in Figure 6 using the IDEF0 format. This format illustrates process flows and the inputs and outputs to and from the five system level functions of the Web MMS.

The first level functional architecture in Figure 6 illustrates the "Provide Web MMS Services" function of the Web MMS. Five system level functions trace one-to-one to the functional requirements listed in the previous 'requirements' discussion. The first function, 'Provide Access', is allocated to the 'System Access' component and awaits the trigger of "Web Address" as a control. It's output, based on this trigger, is the display of the "Web MMS Home Page", which contains within it the "Login Request", which triggers the second function of 'Accepts Inputs and Provides Feedback', allocated to the 'Interface' component and resulting in five outputs, including "main" and "sub-system menus/displays", "username/password request" and "user input requests" and "reports". These outputs are provided based on the inputs of "username/password" and "user input/requests". A "user input" is an actual typed entry, while a "user request" is a selection from the screen. The internal trigger of "data handover" controls the third function, "Calculate Responses to Inputs", allocated to the 'Logical Systems' component. Unlike the third function which has only internal inputs and outputs, the fourth, 'Communicate with Mainframe", allocated to the 'Mainframe Interface' component, has two external outputs of "request username and password verification" and "request for mainframe data". The fifth and last system function, 'Provide Maintenance Mode', allocated to the 'Maintenance' component, receives a trigger from the second function to provide "maintenance access", which does not require a loop through the 'Logical Systems' component because that function has already filtered each user's menu options based on that user's access credentials. This was a deliberate (although secondary; resulting from the iterative process) architectural design intended to reduce processing time and "steps for changes", both stakeholders' requirements. The resulting outputs from this function will be software code changes.

Tracing two of the use case scenarios ensures the functional completeness of the proposed architecture, as illustrated in Figures 7 and 8. The steps in the architecture that correspond to the steps in the use case scenarios are traced with blue lines and numbered. Each number also corresponds to the use case steps for further clarification. As is demonstrated by these figures, a logical and continuous flow exists from one step to the next. This was certainly not the "first crack", as tracing the use case scenarios exposed several flaws with the original architecture and resulted in several iterations of architecture adjustment and requirement analysis.

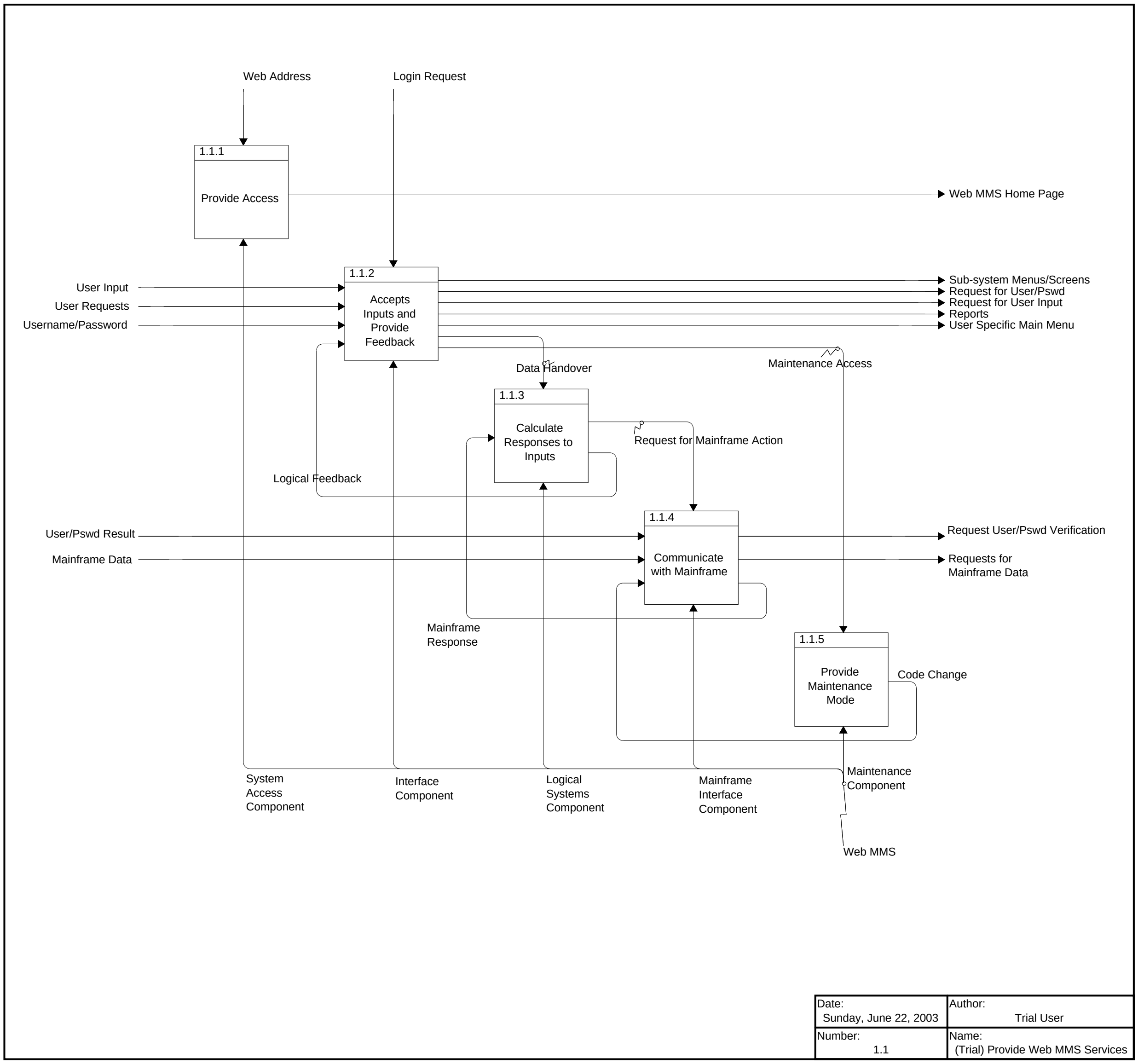
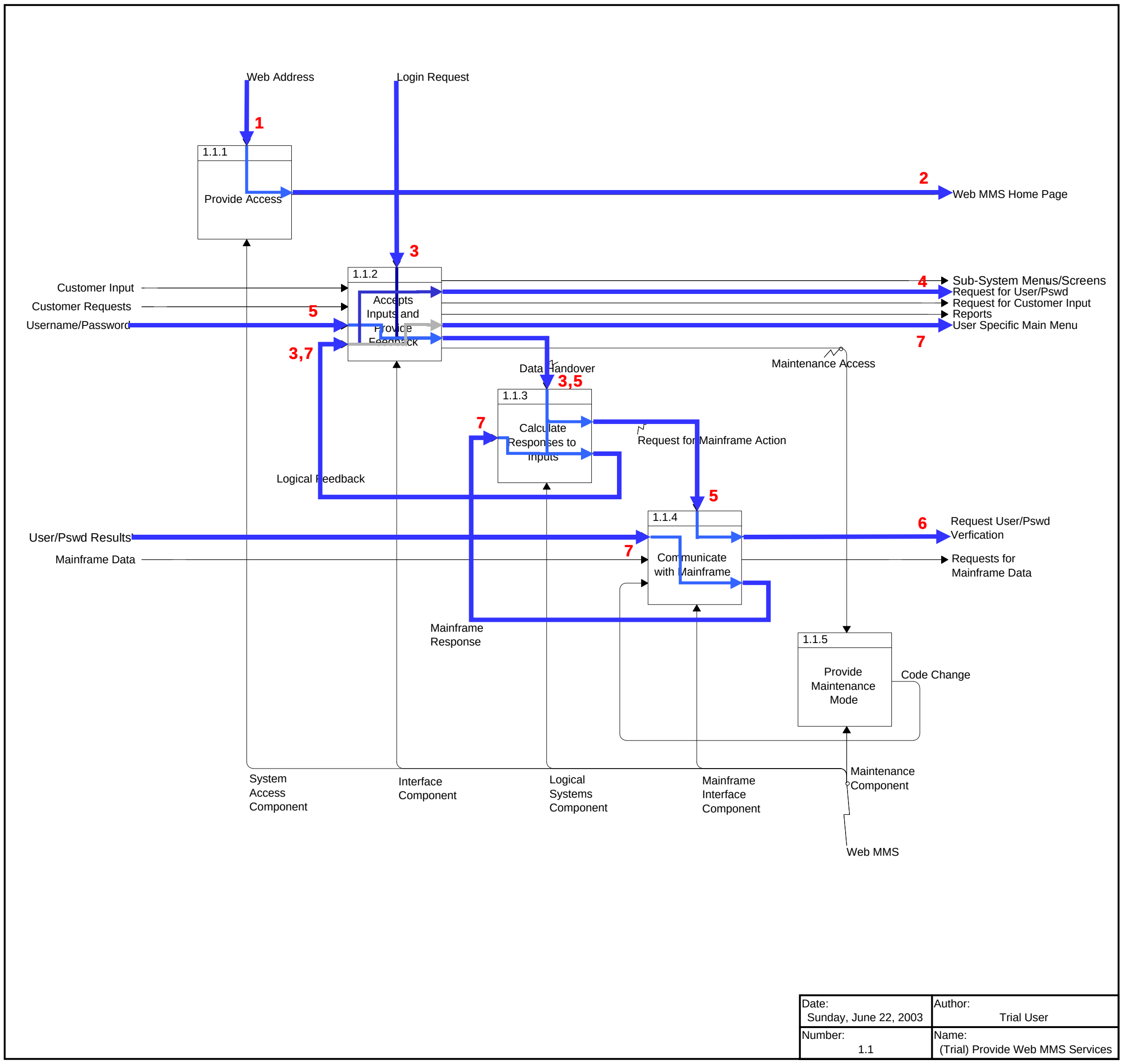
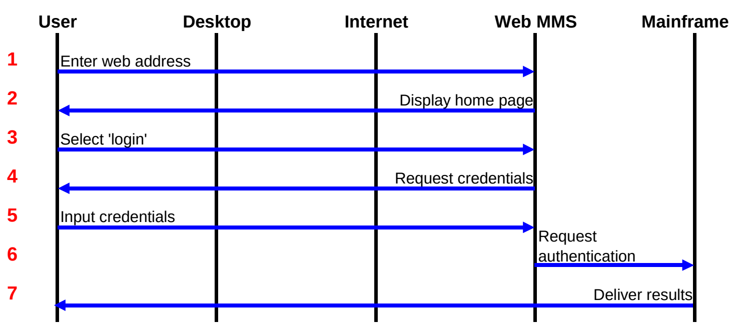


Figure 6, "Web MMS" First Level Functional Architecture

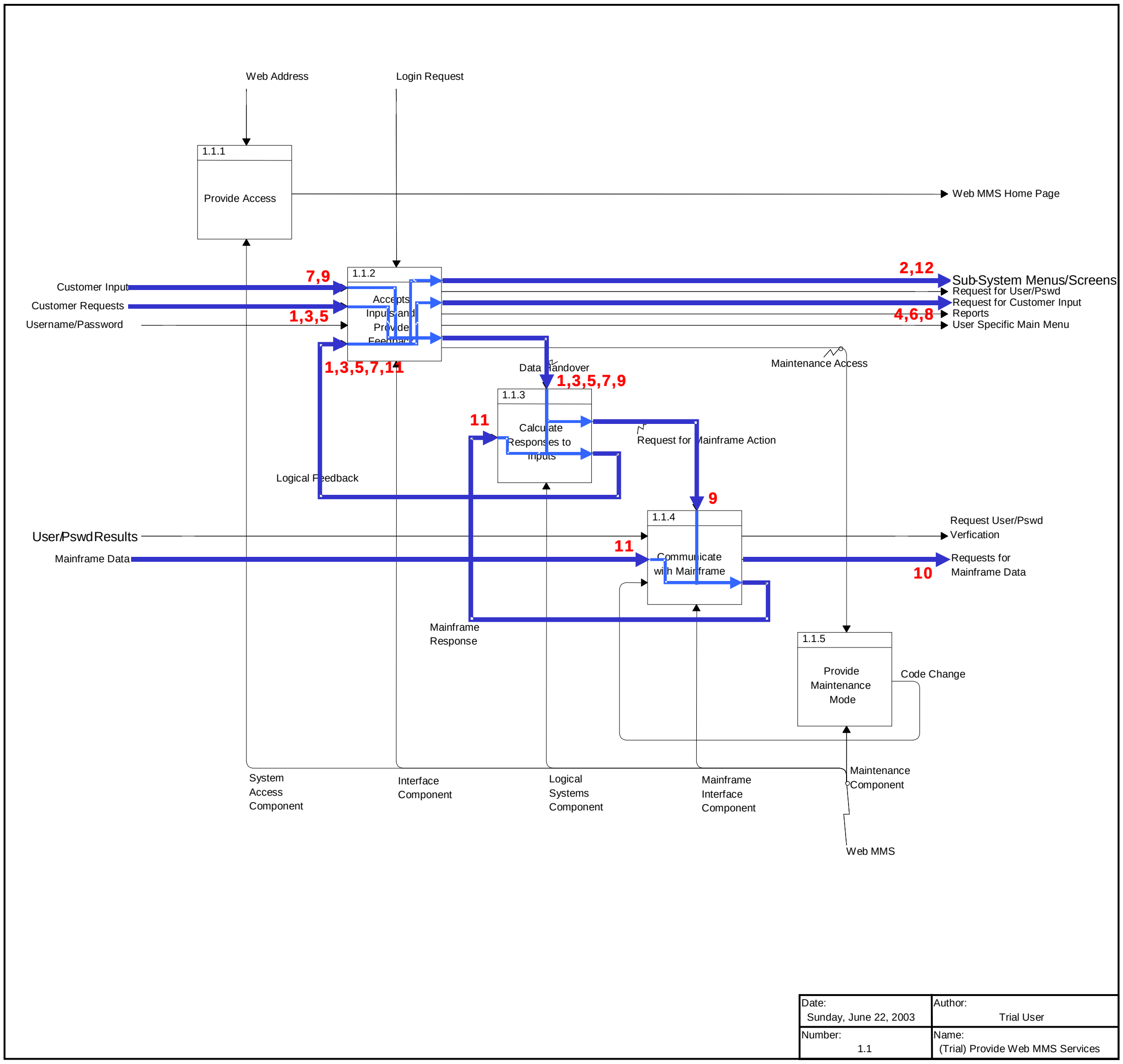


Verify Username and Password



- The user enters the web address of the Web MMS using an Internet accessible desktop computer
- The Web MMS displays the Web MMS home page / partial menu
- The user selects 'login'
- Web MMS requests username, password and domain
- User inputs username, password and domain
- Web MMS requests authentication from mainframe
- Mainframe delivers results, Web MMS displays main menu (verified) or request to re-enter (max 3x)

Figure 7, Tracing 'Verify Username and Password' Use Case Scenario



Resume Assembly of a Product

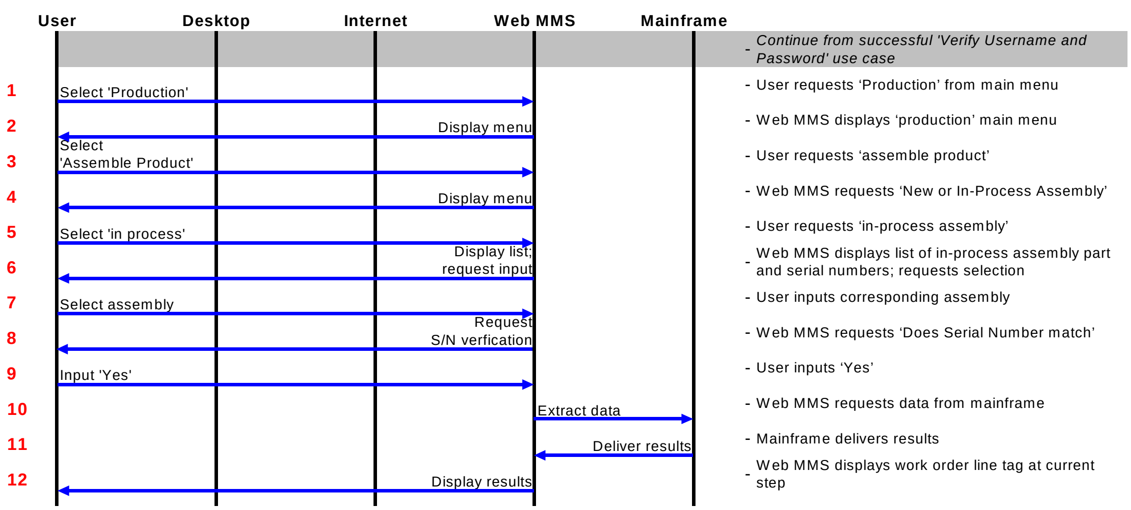


Figure 8, Tracing 'Resume Assembly of a Product' Use Case Scenario