LTA 18

NASA - AMATYC - NSF
Project Coalition

Kennedy Space Center

Launching into the Future

Mathematics for Engineering Technology

Industrial and Management

Capital Community College

In Firing Room No 1 at KSC, Shuttle Launch Team members put the Shuttle System through an integrated simulation.

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Launching into the Future

Mathematics for
Industrial and Management Engineering Technology

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Karen Gaines has degrees in Mathematics and Electrical Engineering. She has worked for McDonnell Douglas as a Senior Engineer with responsibilities for designing, developing, and testing hardware and software for avionics units for commercial aircraft. Karen was accepted into Project Next, sponsored by the Exxon Corporation. At St. Louis Community College, Karen is working with writing teams for Intermediate Algebra and for Differential Equations to develop classroom modules based on applications.

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Kristine Kennedy began working for NASA in 1988 as a cooperative education student in the Launch Processing System (LPS) Division of the Shuttle Ground Engineering Directorate. Upon completing her Bachelor of Industrial Engineering degree at Georgia Tech in 1993, she returned to the LPS Division as a Computer Engineer. In 1996, Kristine joined the Checkout & Launch Control System project as a Human Factors Engineer. She was involved with modernizing KSC's launch control facilities and with designing new computer consoles to be used during launch activities. Kristine transferred to the Johnson Space Center in Houston, Texas, in 1998 where she is working as a Flight Controller for Space Station and Shuttle robotics.

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Launching into the Future

Background

The primary NASA center for the test, checkout and launch of manned Space Shuttles is located on Merritt Island in Florida, just north of Cape Canaveral. The Launch Complex facilities include the Launch Control Center (LCC) - which can be considered the brain of the Complex. The LCC contains two primary firing rooms and one backup firing room. These firing rooms are where engineers monitor and control the Shuttle assembly and the checkout and launch operations. Control of the Shuttle is turned over to Johnson Space Center in Houston, Texas when the solid rocket boosters ignite.

The Launch Complex facilities were originally designed to support the Apollo lunar landing program and have been in operation since the 1960's. Although the complex has undergone some modifications to support processing and launching the Space Shuttle, the firing rooms in the LCC still contain the original equipment. NASA has recently begun a five-year program to completely refurbish and update these rooms. The motivation for this upgrade includes NASA's need for more flexibility, both in how the Center is used, and what types of vehicles can be tested, controlled, and launched from the LCC. Because of advances in technology that provide new capabilities and possibilities, **every** aspect of the center has been subject to thorough examination. As part of this upgrade, the rooms will be renamed Operations Control Rooms (OCRs).

The entire process of redesigning the rooms and equipment involves personnel from many areas, including Human Factors Engineering, Mechanical Engineering, Electrical Engineering, Safety Engineering, Facilities Engineering and Maintenance. It is imperative that all who are involved in this process work closely as a team and maintain regular contact with each other. Each team member is not only responsible for investigating specific components of the re-design, but also must be mindful of accommodating requirements determined by others on the team. The work by the team must be a very dynamic, creative and flexible process.

Project Overview

In this project, you will experience a process that incorporates components of the actual design process used by NASA. You will work specifically with refining equipment prototype development and the layout of the main floor of an Operations Control Room (OCR). This work requires that you work both in an Engineering Group on very specific tasks as well as on a more comprehensive Design Team. You will be given certain criteria and constraints that have already been determined from previous evaluations and studies concerning the work needs of personnel working on the main floor of an OCR. You will also be given material specifications and costs, as well as a scaled drawing of the first firing room (renamed Operations Control Room1 – OCR1) to be re-outfitted.

Imagine that you have just been notified that you were assigned to one of the OCR Design Teams. Each of these Design Teams will be in charge of providing NASA Headquarters with:

1) Dimensions of the System Engineer (SE) console, Console Support Module, and Peripheral Housing prototypes that take into account principles of anthropometry (how people vary in size) as well as work needs (space needed for books, keyboards, etc.). Specifically, you need to determine:
   - Appropriate heights and depths of the primary and secondary desk tops for the SE Console. (Height for the desk tops should be measured from the floor to the bottom of the desk tops. Each desk top is 1 inch thick.)
   - Height and depth of the desk top for the Console Support Module.
   - Height of the Peripheral Housing units. The top of the Peripheral Housing unit must be level with the top of the desk top on the Console Support Module. **Note:** The top of the Peripheral Housing is made of the same material as the desk top, which is 1 inch thick.
2) Dimensions for both a wedged and straight connecting table, which will allow for extra desk space and storage, and will allow the SE consoles to be joined together into an "eyebrow" configuration.
3) The total cost for each of the following, using pre-determined material specifications.
   - Materials to build the required number of System Engineer (SE) Consoles, wedged and straight connecting tables between SE consoles, Console Support Modules, and Peripheral Housings (for printers and fax machines)
   - Painting (using two coats) and carpeting the room
   - Outfitting the room with the required number of chairs
4) A scaled drawing of a room layout for the **main floor** of an OCR, which accommodates the layout requirements for the teams of personnel.

Upon completion of the work, each Design Team will present a design to NASA Headquarters. The best of these designs will then be selected for implementation.

Project Tasks

The project is broken down into three stages: 1) Initial Meetings of the Design Teams and Engineering Groups 2) Engineering Group Investigations 3) Design Team Proposal Work.

Initial Meetings of the Design Teams and the Engineering Groups: At these meetings:

1) You need to introduce yourself to your teammates, and through discussion of the project determine your strengths as a team member.
2) It is imperative to identify all the tasks required in order for the Design Team to complete the project. The Design Team members must agree on an assignment of duties and determine how the team will work to bring all the components together.
3) Even though the Engineering Group tasks are well spelled out in Appendix A, you will need to determine how your group will work to ensure efficient collection and synthesis of information, as well as how to present the information in a written report.
4) You need to lay the groundwork for open communication within your teams. Discuss how you see your team working to ensure that all parts of the project are addressed and that everyone contributes significantly. Some examples of roles that you may take on are: Manager – overseeing the overall project and communicating between the various members; Technical Drawer – creating the scaled pictures; Transcriber – creating the finished documentation necessary; Artistic Designer – working on the final presentation of the room design.

Engineering Group Investigations: Based on physical room limitations, equipment measurements, and input from the NASA engineers, there are criteria that must be incorporated into any design of a room layout. To ensure standardization, it is mandatory that Engineering Group members work together to collect, analyze and organize material for their specific tasks. Your goal as a member of an Engineering Group will be to become an expert in your area so that you can communicate essential material to your Design Team. Each Engineering Group will prepare a written report, including appropriate tables and data for their particular area of investigation. The reports from the Engineering Groups will be used by the Design Teams as they complete the project.

Design Team Proposal Work: In these meetings, the Design Team members use information from the Engineering Groups and Appendix B to work together to complete the major tasks of the assignment (previously outlined in the Project Overview). Each team must prepare a presentation and written report of its total design. Each report must include: appropriate additions to the design sketches for the SE Console and Console Support Module, showing desk top height and depth; a sketch of the "wedged" and straight connector tables complete with all appropriate dimensions; a scaled room layout; a cost breakdown for SE Console, wedged & straight connectors, Console Support Module, Peripheral Housing; cost for carpet and paint; and a copy of the written report produced by each Engineering Group. The written report must also include details of how the various decisions were made and include any appropriate computations and/or tables. Each team member is responsible for carefully reading and editing the final report to ensure that everyone agrees on the information and understands all computations and decisions made.

Appendix A
Engineering Group Tasks

Engineering Group # 1
Mechanical Engineering

Overall Task: Make dimension and scaling decisions about equipment and the layout of the Operations Control Room (OCR). Create two dimensional models of the floor space needed by equipment. Describe your results and the methods in a written report.

- Gather information about space needs requirements for 3 ring binders and standard keyboards. This information, along with information from Engineering Group # 2, will help each Design Team determine the appropriate depth of desk tops for both the SE console and Console Support Module. It will also help each Design Team determine the height difference between the two desk tops on the SE console.
- Determine the dimensions for both straight and wedged connecting tables used for extra work surface between consoles. Each wedged table must have a mid-depth width of at least 22 inches, and one side must be angled at 20 degrees from front to back while the other side must be straight (see Figure 2). Both the wedged and straight connecting tables will be used to "join" together the SE consoles, and must run the entire width of the console (from the back of the unit to the front edge of the primary desk top).
- Create an appropriate scale so that the diagram representing the Operations Control Room shown in Figure 1 will fit on a poster board.
- Using this scale, create two-dimensional scaled models for the floor space needed by the SE console, connecting tables (both straight and wedged), Console Support Module and Peripheral Housing. Color-code these units for ease in identification.
- Prepare a written report that includes the group's results as well as a description of the processes used to obtain them. Each member of the group must feel comfortable with all parts of the report, and understand fully how the various decisions were made. The report will be used by each of the design teams.

Appendix A (Continued)

Engineering Group # 2
Human Factors Engineering

Overall Task: Gather statistical information on body measurements that will influence the design decisions for the consoles. You need to ensure that the height and depth of the desk tops meet the needs of the greatest number of people. Prepare a written report that includes the collected information, the processes used to acquire the information, and the group's recommendations. Each member of the group must feel comfortable with all parts of the report, and understand fully how the various decisions were made. The report will be used by each of the Design Teams.

- Using an appropriately chosen sample of people of various sizes with equal numbers of men and women, measure the following:
  - arm length from elbow to index finger tip
  - arm length from shoulder to index finger tip
  - eye height in sitting position (from the seat)
  - eye height in standing position
  - height from floor to top of knee in sitting position
  - height of mid-thigh above seat of chair in sitting position
  - buttock to knee length in sitting position

- Create a table, broken down by gender, which shows the extremes (minimum and maximum) and mean for each of these categories. Compare these values to statistics obtained from an authoritative source, and make any adjustments that you feel are necessary. (Note: This information can be found in textbooks on Anthropometry or Ergonomics, or in the MIL - STD - 1472E, a Military Standard document. You need to consult your library or find appropriate information on the internet. You must include an appropriate acknowledgment of your information sources in the written report.)

- Use your information to determine recommended desk top heights and depths for SE console and Console Support Module.

- Use your information to check whether the previous determination of console height seems appropriate, allowing people to see over the consoles when standing.

- Measure space requirements for typical chair positions from front of desk tops. This should include working position as well as rolled out position when leaving the console. Use these measurements to determine how much space is needed for proper chair motion, while still providing for an unobstructed walkway behind a typical work-station at all times.

Appendix A (Continued)

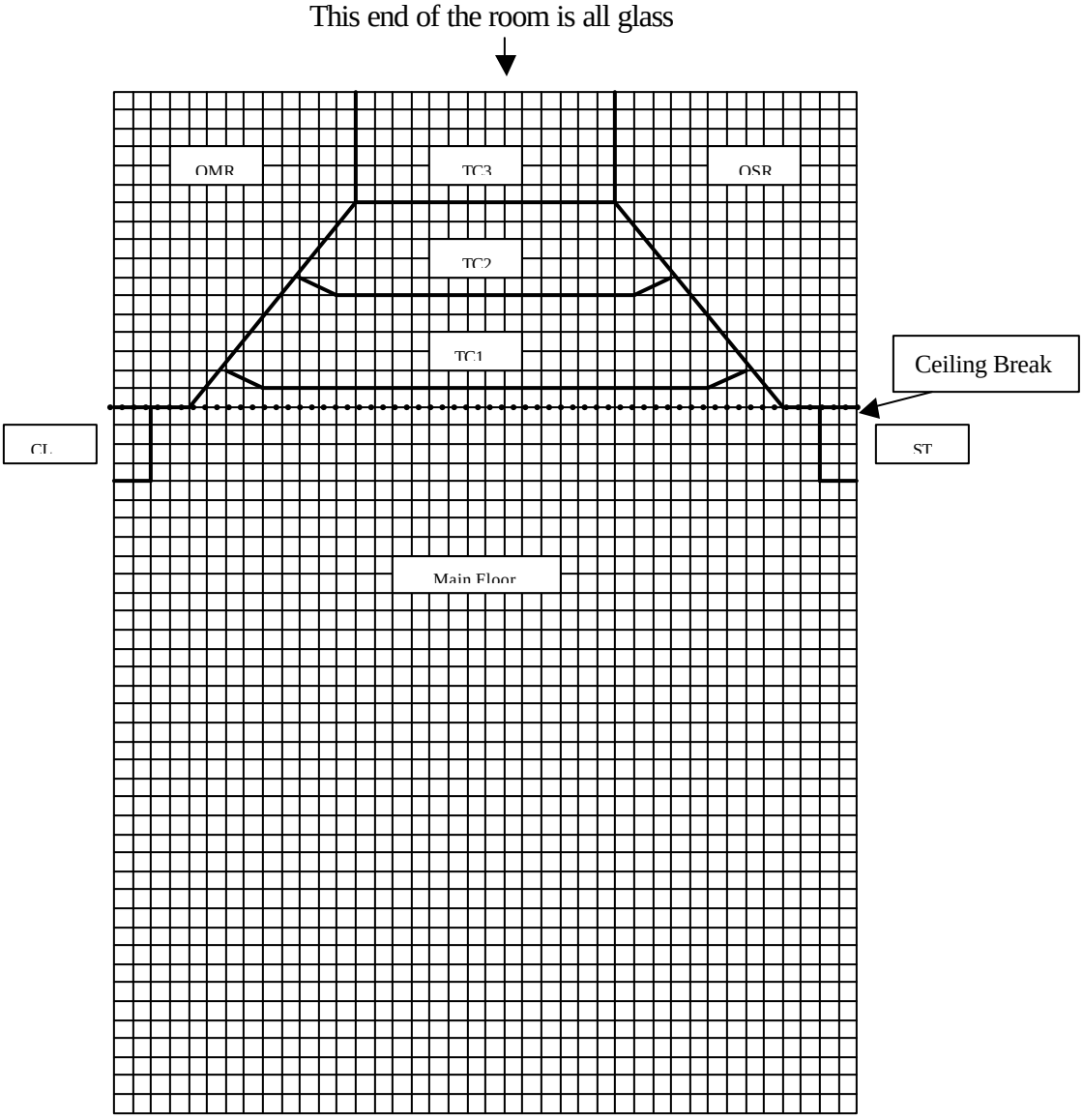
Engineering Group # 3
Facilities Engineering

Overall Task: In order for your Design Team to determine the costs of carpeting and paint, they will need to determine the surface areas of the floor and walls.

- Calculate the surface area, in square feet, of the four walls in OCR1 (See Figure 1 on the next page). Assume that the ceiling height is 12 feet 9 inches above the main floor and is to 27 feet 6 inches above the floor of the top tier. In Figure 1, the change in ceiling height is indicated as "ceiling break". At this break, assume there is an "upper wall", running the entire width of the room parallel to the front of the first riser. This upper wall extends from the ceiling of the main floor all the way up to the maximum height of the room. Take into account that the front of the room is all glass so that the launch of the Shuttle can be observed. Allow an extra 5% of your computed amount of paint for touch up work, and the extra half walls that will separate the risers.
- Calculate the total area, in square yards, of the surfaces that will be carpeted, including the front (or vertical surface) of the risers for each of the TC tiers. The first riser is 1 foot 6 inches high, the second riser is 2 feet high, and the third riser is 2 feet 6 inches high. Since there are actually stairs on each side of the risers leading to the next level, you should allow 15% extra for these stairs and for scrap.
- Prepare a written report that includes the group's results as well as a description of the processes used to obtain them. You may want to consider creating sketches of the various wall areas to help clarify your presentation. Each member of the group must feel comfortable with all parts of the report, and understand fully how the various decisions were made. The report will be used by each of the Design Teams.

Appendix A (Continued)

Figure 1
Operations Control Room (OCR1)



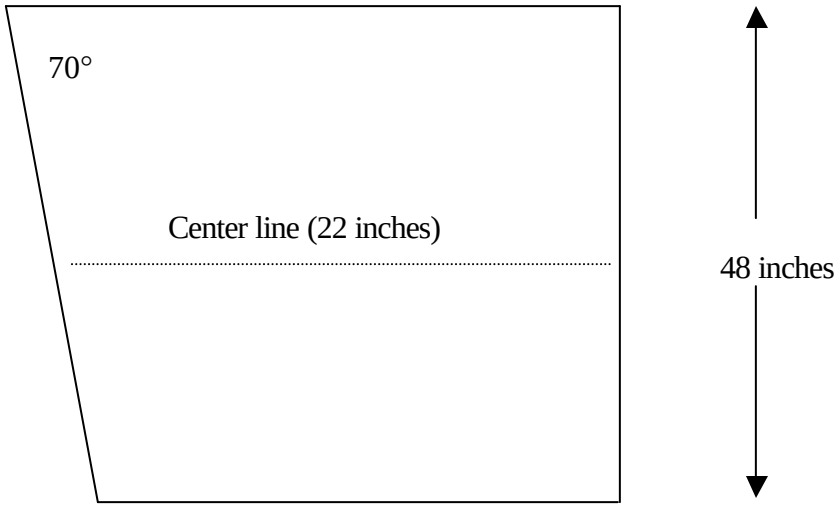
Grids are 2 ft. x 2 ft.

OMR – Operations Management Room
OSR – Operation Support Room
TC1-3 – Test Conductor Tier
Main Floor – contains: System Engineer/Console Support Modules
CL – Chair Lift
ST - Stairs

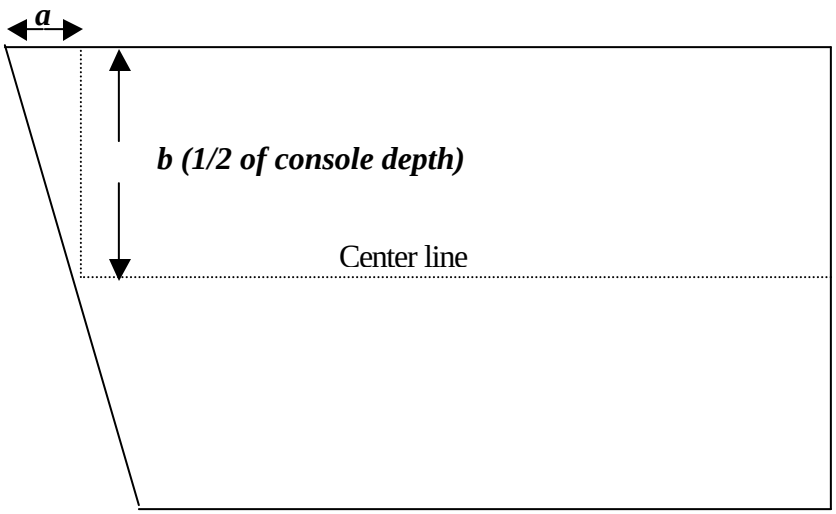
Appendix A (Continued)

Figure 2
Wedge Dimensions

The pre-determined wedge dimensions are indicated below (not to scale).

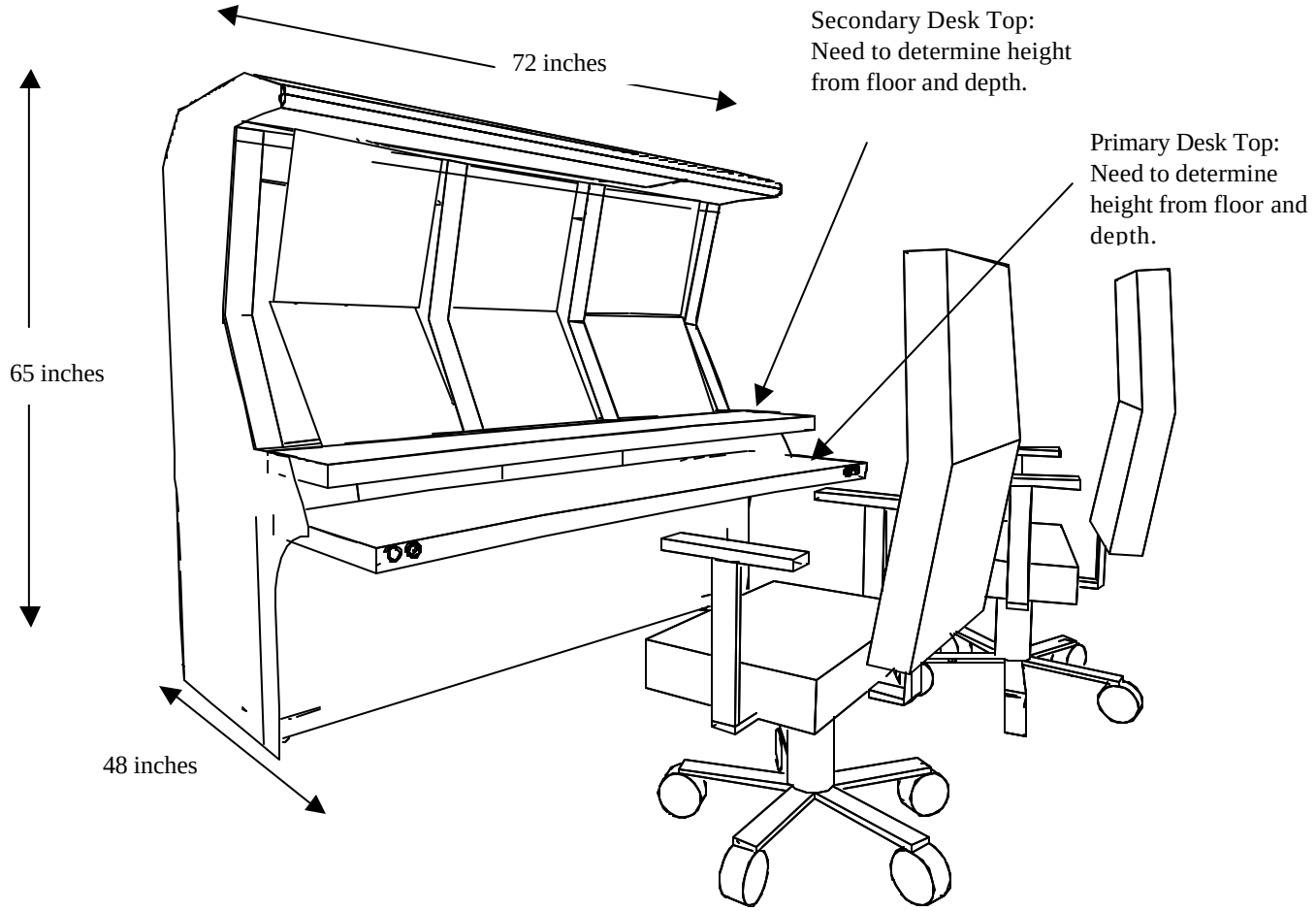


To determine the lengths of the unknown bases on the trapezoidal wedge, use the fact that the ratio of ***a*** to ***b*** is 0.36.



Appendix A (Continued)

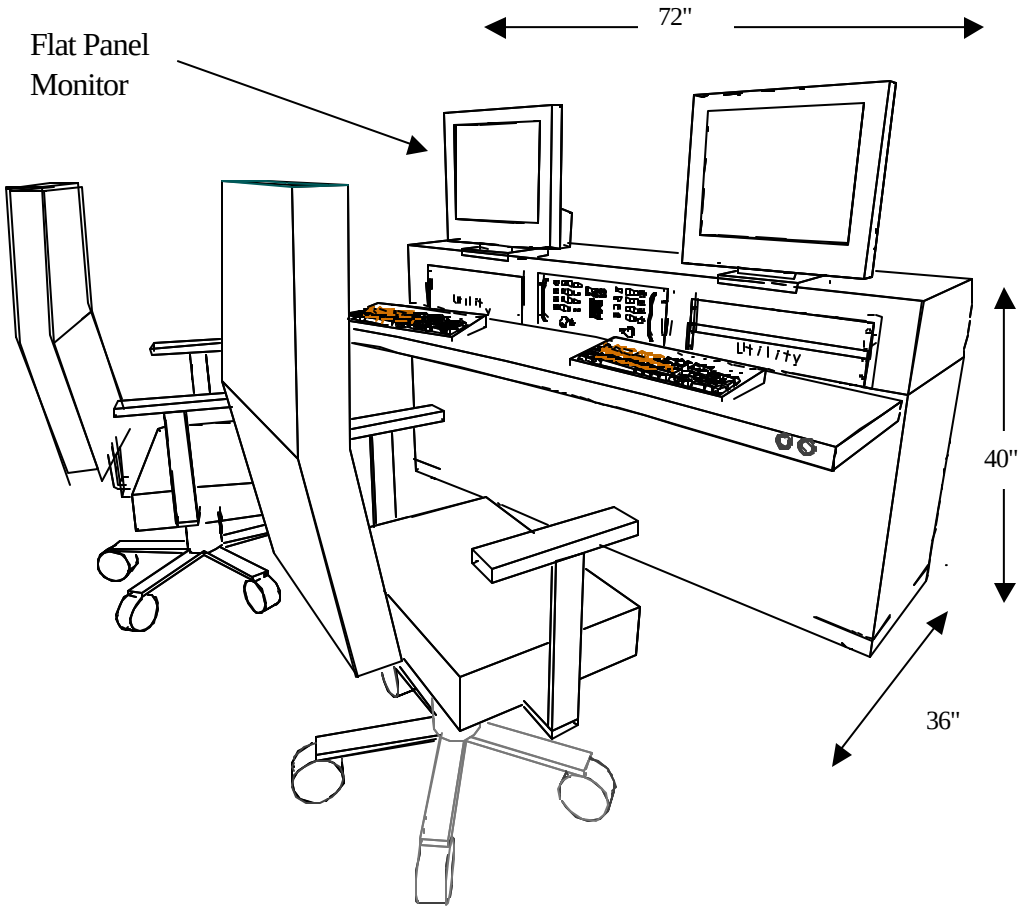
System Engineer (SE) Console



Note: The total depth of the console is 48 inches from the back of the unit to the front of the over hanging Primary Desk Top. Both desk tops are bolted to the frame of the basic console. The basic unit (without overhanging desk tops) must be at least 26 inches deep in order to accommodate monitors and other equipment housed in it.

Appendix A (Continued)

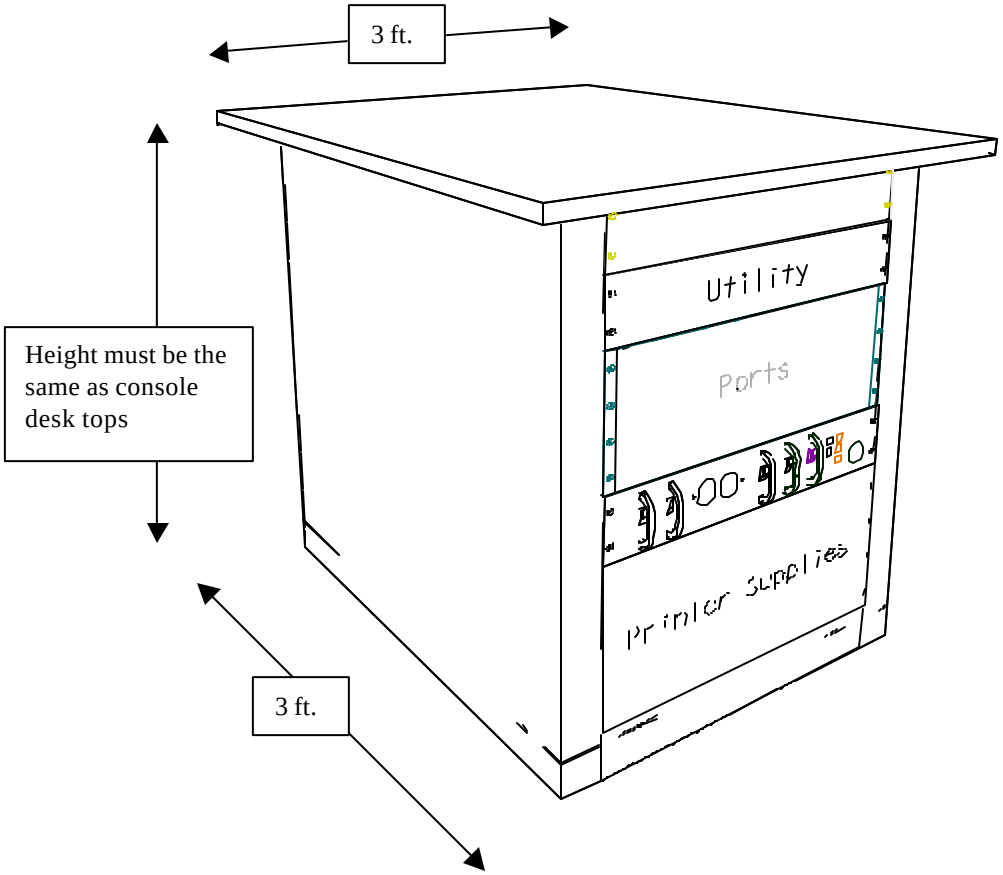
Console Support Module



Note: The depth of the console is 36 inches, measured from the back of the console to the front of the overhanging desk top. The desk top is bolted to the basic console unit. The basic unit (without overhanging desk top) must be at least 20 inches deep in order to accommodate equipment housed inside.

Appendix A (Continued)

Peripheral Housing



Appendix B
Design Group Criteria and Information
Provided by NASA Engineers

Criteria for Layout of OCR1 Main Floor

- There are 16 teams. Each team consists of:
  two SE consoles (2 people at each console),
  one Console Support Module (2 people at the console), and
  two Peripheral Housings units located to be readily accessible from the Console Support Modules.
- Groups of four teams should be clustered together for easy access to each other (these groups may be performing different tasks to test and monitor a given system).
- Engineers want to maintain a horseshoe or "eyebrow" design within the clusters of teams.
- Adjacent SE consoles must have either a straight or wedged connecting table between them that is the same height as the primary desk top. This will be used for additional desk top space, phone storage, etc.

Specific Requirements for Particular Components

- To ensure the strength and integrity of the consoles, each steel face must be made from a continuous rectangular piece. If a sheet of steel must be cut to accommodate anything (angles and/or monitor openings), the scrap material can no longer be used. If a sheet of steel has only a straight edge cut (no angles or openings) the remaining piece may be used elsewhere.
- The depth of the overhanging desk top must be subtracted from the SE console and Console Support Module depth to determine the necessary width for the steel face on the sides of the consoles.
- In the SE consoles, each row of monitors must be supported by internal shelving.
- In the Console Support Modules, an internal shelf must be inserted at desk top height to support the recessed equipment.
- The overhang of the SE console will use steel sheeting only at the top. The cost for the rounded part and bottom of the overhang are included in the standard cost per console. ($300 + $1000 as shown in the Cost of Materials Table on the next page)
- All desk tops, connecting table tops and peripheral housing tops are to made from the Dupont Corian® Desk top material.

Appendix B (Continued)

Cost of Materials

Material	Cost
Anti-Static Berber Carpet	$43.95 per square yard, installed
Latex base, eggshell finish paint	$19.99 per gallon Each gallon covers 200 square feet
Upholstered Chair with vinyl headrest, lumbar support, adjustable height, adjustable recline	$827 per chair
Zinc Plated, custom colored, sheet steel for framework and exterior panels	$110 per 4'x12' sheet
Solid composite Dupont Corian® Desk top	$85 per linear foot
Shelving and Mounting Hardware	$11 per linear foot
Wiring, junction boxes, bulbs, ballast, dimmer switch for SE Console	$300 per console
Wiring, junction boxes for Console Support Module	$125 per console
Casters, blank panels, grounding straps, nuts, bolts for SE Console	$1000 per console
Casters, grounding straps, nuts, bolts for Console Support Module	$ 650 per console

Note: Desk tops are bolted to supports on the sides of the basic console units. Also, the SE console has two desk tops as shown in the drawing in Appendix A. Cost of the desk top material is not dependent upon depth, only length.

Appendix C
Glossary of Terms and Acronyms

Terms

Anthropometry – The study of how people vary in size.

Console – A desk or workstation that includes both monitoring equipment as well as a desk top on which to do work.

Console Support Module – The desk or workstation at which support personnel work.

Design Team – A group of engineers from various disciplines who work collaboratively to design something.

Desk top – The working surface area for the engineers.

Engineering Group – A group of engineers of a specific discipline who work collaboratively to assemble information necessary to be used in a design process.

Eyebrow – A configuration of furniture which is shaped in an arc, or eyebrow.

Linear Foot – A measurement of length independent of width.

Operations Control Room – The name for any one of the redesigned firing rooms where the engineers monitor and control the Shuttle assembly and the checkout and launch operations. The room consists of a main floor as well as three tiers.

Peripheral Housing – A cabinet used to house fax machines, printers and other peripheral equipment.

Riser – A step or its' vertical surface.

System Engineering Console – The desk or workstation at which a system engineer works.

Tier – Another level or step up from the ground floor.

Acronyms

LCC – Launch Control Center

NASA – National Aeronautics And Space Administration

OCR – Operations Control Room

SE – System Engineer