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CENTRIFUGE MEDICAL MONITORING STATION DESIGN CONCEPTS

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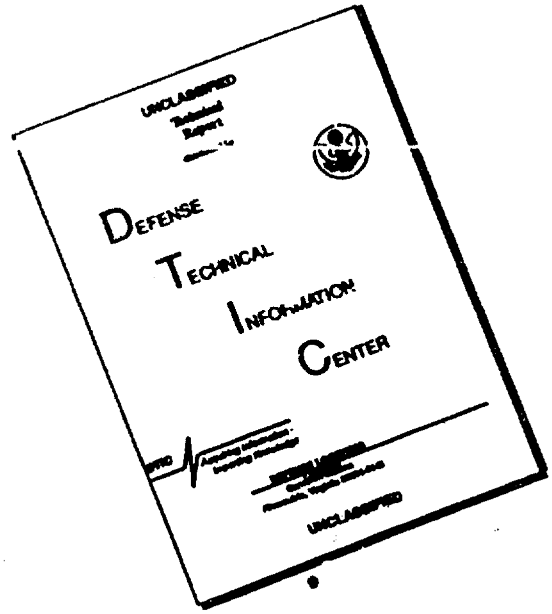

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Human centrifuges have been relatively few in number and unique in design. The advent of high-G centrifuge training for aircrew of high performance fighter-type aircraft promises to result in increased centrifuge use, the building of additional facilities, and modernization of existing facilities. Assurance of maximum safety for the human occupant in a centrifuge gondola is a high priority. The basic requirements of a medical monitoring workstation are described. Centrifuge medical monitoring is a brief but high task load activity. An optimal medical monitoring workstation design is a valuable asset for providing the safest environment for aircrew during centrifuge training and volunteer subjects participating in acceleration research.

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INTRODUCTION

The recognition that rapid-onset, high-sustained $+G_z$ acceleration characteristics of advanced fighter aircraft increases the risk of in-flight loss of consciousness (G-LOC) has resulted in more activities that require the use of a human centrifuge. The current major uses of human centrifuges include research and aircrew training. Additional uses include aeromedical evaluation of potentially G-sensitive aircrew and orientation exposure to the high G-environment. Most current centrifuge training programs are designed for initial training only of aircrew to assure optimum performance of protective anti-G straining maneuvers. Since large numbers of aircrew remain to undergo initial centrifuge training, it will likely be several years before we were able to even consider refresher training or centrifuge use for maintaining aircrew acclimation to the high G environment. These periodic uses of the centrifuge are a logical and potential extension of current programs. Centrifuge use will therefore remain extremely high for the forseeable future with additional centrifuges likely to be constructed.

Designing new centrifuges and/or upgrading existing facilities is part of the current emphasis relative to the acceleration activities discussed above. Since acceleration research has been conducted in relatively few, very specialized centers, centrifuges have been designed and constructed in highly unique configurations. Although the overall centrifuge facilities and capabilities may be unique, certain configurations and operational requirements are universal. Medical monitoring of the human occupant requires certain safety considerations be designed into the centrifuge facilities. This includes continuous audio and video monitoring of the occupant, emergency stopping of the centrifuge, and various other specific physiologic monitoring capabilities. Although not all training programs include all aspects of medical and physiological monitoring, it is consistent with the principles of maximum safety to include as much non-invasive, non-encumbering monitoring as possible for immediate response to the most likely potential causes of medical misadventure. For high $+G_z$ centrifuge stress this includes electrocardiographic (EKG) monitoring, since there is significant cardiovascular stress which has been associated with potentially life-threatening cardiac dysrhythmias. Centrifuge acceleration research has a history of safety, thanks to a long line of conscientious aeromedical scientists. Part of this safety record is undoubtedly due to the very selective nature of the subject qualification standards for allowing human exposure to these stressful environments. The relatively restrictive standards for exposure of human subjects participating in centrifuge research studies is not possible with large scale training of fighter aircraft aircrew. It might be argued that these aircrew have already demonstrated an acceptable tolerance to the $+G_z$ environment through an operational trial by fire. To a certain extent this is true; however, it must be recognized that current centrifuge high $+G_z$ training exposure profiles exceed routine aerial combat maneuvering profiles (1). It is likely that the high, sustained $+G_z$ profiles of the centrifuge training programs may actually be the most stressful acceleration exposures aircrew will experience. For this reason, optimal training safety dictates that EKG monitoring be recommended for aircrew training. Other non-invasive physiologic monitoring would also be advantageous. The implementation of physiologic (medical) monitoring techniques for ensuring safety must be balanced against aircrew acceptability, excessive encumbrance, technique reliability, and excessive time requirements imposed by instrumenting the trainee. A balance of these factors will ultimately define the extent of monitoring that each centrifuge program will employ in its training and research programs.

Medical monitoring of human exposure to stressful acceleration environments is generally the responsibility of a flight surgeon or research medical officer thoroughly familiar with the high G environment. The actual monitoring of human exposure on a centrifuge is a short but high task load responsibility. Several variables must be coincidently monitored to ensure safe human exposure. For this reason, design of an optimal monitoring workstation is highly desirable. Although it is likely that a single workstation configuration is not universally optimal for all facilities and all projects (research and training), it is worthwhile for experienced centrifuge medical monitors to provide a description of what they consider an optimal design based on experience. If nothing else, such a description does provide a starting point from which less experienced designers can develop improved or unique monitoring configurations. With these concepts in mind, the following medical monitoring workstation description is provided.

MEDICAL MONITORING WORKSTATION DESCRIPTION

A medical monitoring station for a centrifuge which is used for research, training, and aeromedical evaluation is described. The design is based on the characteristics of several existing centrifuge facilities and years of experience in monitoring various types of human exposures on these centrifuges. For this reason, many of these ideas are not original. It is assumed that the medical monitoring station is located with ready access to the centrifuge gondola and its human occupant. Ready accessibility and rapid transition from the medical monitoring station to the centrifuge gondola and the subject cannot be overemphasized. It is preferable that the gondola be accessible in all possible locations from ground level. Extraction of a subject from the gondola at ground level should also be able to be rapidly accomplished with ease and safety.

The medical monitoring station should be located such that external distractions are minimized. Ready communication with other members of the centrifuge operations team should be facilitated. The medical monitor should be afforded a quiet, comfortable, and well-lighted environment. The general configuration shown in Figures 1a and b is similar to what currently exists at many facilities. Direct (window) or indirect (video) observation of the centrifuge at all times is highly desirable but not absolutely a requirement for the medical monitor.

The medical monitor console configuration is the most critical aspect of the workstation. Figure 2 illustrates the medical monitoring console layout. The console is divided into quadrants. A flat desk top, with hidden storage, provides a platform for writing. The smaller supplies box should store pens, pencils, and other materials. The larger box should store reference material, forms, and paper. An audio speaker should provide clear voice communication from the human in the centrifuge gondola. A flexible, gooseneck microphone with an intermittent or continuous audio communication button provides medical monitor contact with the subject in the gondola. Although headphones with attached microphone are frequently used, it must be considered less desirable. Each quadrant of the console will be described separately in more detail.

The color video monitor, in the upper left quadrant, is the most important part of the medical monitoring console. Figure 3 shows the details of the requirements that should be displayed. Since the medical monitor centers his attention on the video monitor it should provide as much of the critical information as possible, without excessive cluttering of direct observation of the subject.

The color monitor should be split-screen with one half showing a close-up of the face produced by a zoom lens color camera. A close-up of the eyes should be possible. The second half of the split-screen should have a full-body view of the subject. An overhead shot is preferable; however, a side view may be acceptable as an alternative. The screen with the facial close-up should have several overlays. This includes the subject's name, the date (DD/MM/YY), the instantaneous $+G_z$-level (two places on each side of the decimal), a real-time clock (HH:MM:SS), instantaneous heart rate provided from a cardiotachometer, and ideally a selectable lead from the electrocardiogram. The whole body view should also have the real-time clock and instantaneous $+G_z$-level. The project title or some other identifier to define the purpose of the exposure is a valuable overlay on this screen and provides a quick reference when reviewing videotapes at a later date. A low light level camera may be required in producing these monitoring images since research with sophisticated wide-field of view tracking tasks may require minimal lighting in the gondola. Other more complex split-screen configurations may be designed to meet specific training or research needs.

The strip chart recorder in the lower left quadrant should have a minimum of 5 channels (2 EKG leads, cardiotachometer, $+G_z$-level, and anti-G suit pressure trace). A time-line, marking seconds, should be present to allow accurate timing of all events recorded. An eight to ten channel recorder is preferable, especially if complex research is being conducted. Other physiologic data in excess of the minimum four channels may be considered mandatory in many laboratories. Although the channels being displayed are important for assuring real-time safety, more channels are generally being recorded concurrently on magnetic tape. The recorder should have a range of speeds for recording critical events. If EKG tracings are being recorded, then the ability to record at 25 mm/sec and 50 mm/sec is necessary. In addition, slow monitoring speeds such as 0.5 to 1.0 mm/sec are a requirement to record the traces, and still preserve paper usage. Direct, on-line computer capture of specific data should be accomplished to provide rapid data analysis and reporting.

The right lower quadrant is the control panel which contains the emergency and medical stop initiators for the medical monitor. The medical stop initiator should be integrated with a facilities warning horn to ensure all available personnel will respond to a true medical emergency. Additional device controls should be concentrated in this area. This specifically includes control of the G-LOC warning devices (2). Optional inclusion of light bar control and anti-G suit inflation may also be included in this quadrant.

The right upper quadrant consists of an EKG oscilloscope with at least 2 leads of real time monitoring (Figure 4). One channel of the oscilloscope should allow selectable freeze framing of either of the two leads. Although the speed of the oscilloscopic traces must include 25 mm/sec, additional speeds would be advantageous as described for the strip chart recorder.

A desk with hidden, lift drawers for paper and supplies is an important accessory for the medical monitor. A microphone with flexible neck adjustment and a speaker to assure two-way audio communication between the subject in the gondola and the medical monitor (and other centrifuge personnel) complete the requirements for the workstation.

Although not a specific part of the medical monitoring workstation, a modern videotape recorder/player with rapid scan review and freeze frame capability is a necessary adjunct to the medical monitor. This equipment provides a permanent record of all human exposures on the centrifuge. Any exposure with significant adverse or unique responses should be archived as part of the facility medical record.

SUMMARY

In summary, a well planned medical monitoring station is a vital part of the safe conduct of all activities performed on a human centrifuge. A large volume of data must be concurrently observed by the medical monitor during the short period (5-15 sec) of a rapid-onset, high-sustained $+G_z$-stress exposure. The high task load can be much more readily handled with a carefully designed workstation. Although human exposures on centrifuges have a long history of safety, today investigation of higher

and higher $+G_z$ levels achieved at very rapid onsets for longer periods is necessary. The hazards for the human subjects are therefore increasing. Aircrew centrifuge training will expose a larger number of individuals to $+G_z$-stress than ever before. Highly experienced medical officers with optimum monitoring equipment and techniques will be required to ensure a continued legacy of experimental safety.

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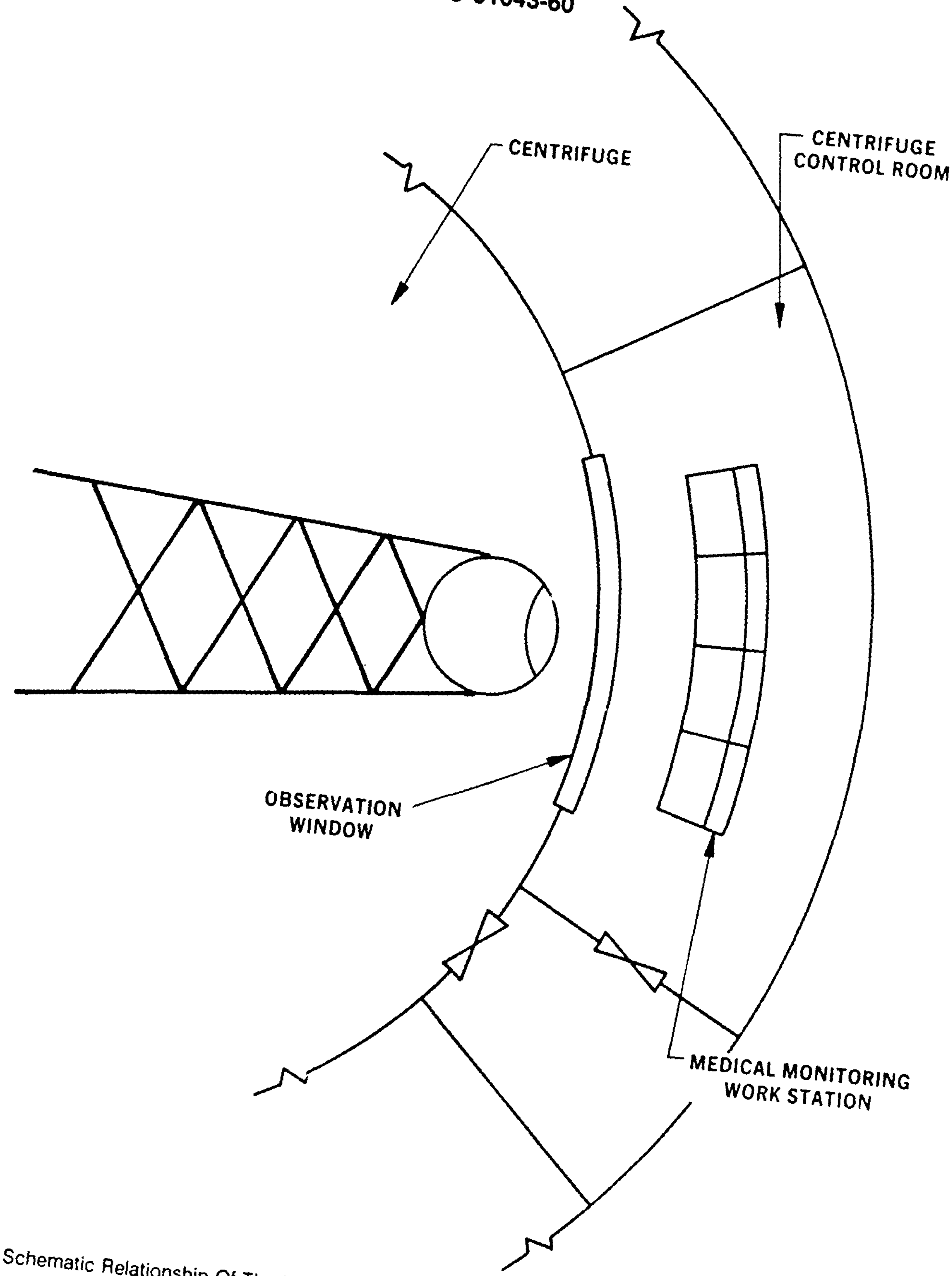

Figure 1a. Schematic Relationship Of The Medical Monitoring Workstation And The Human Centrifuge.

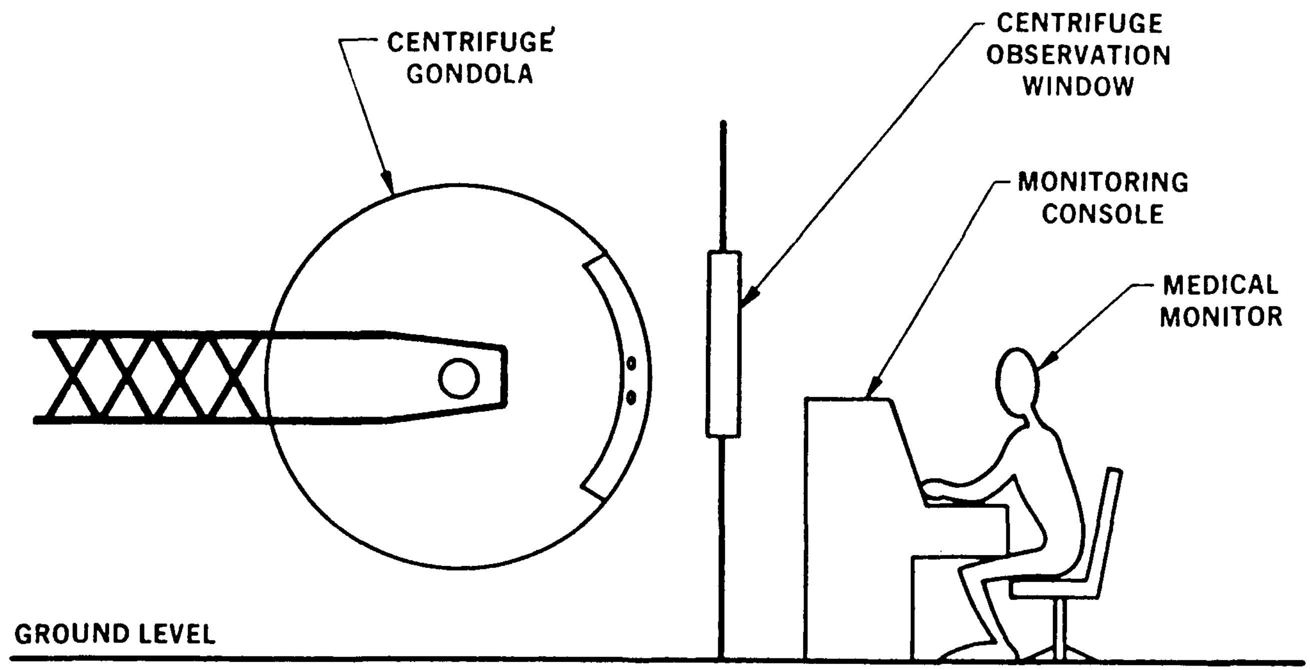

Figure 1b. Schematic Relationship Of The Medical Monitoring Workstation And The Human Centrifuge.

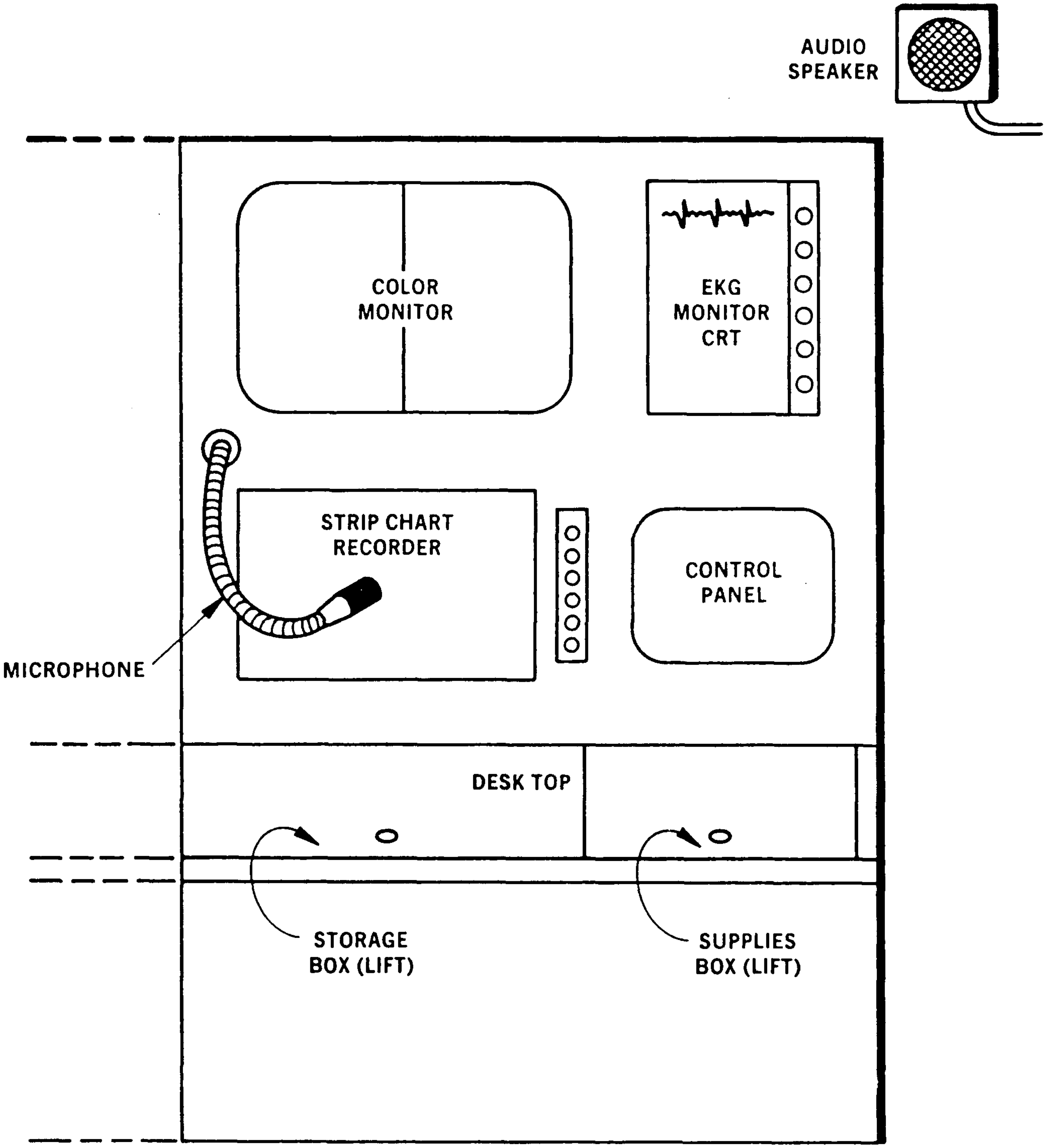

Figure 2. Monitoring Workstation.

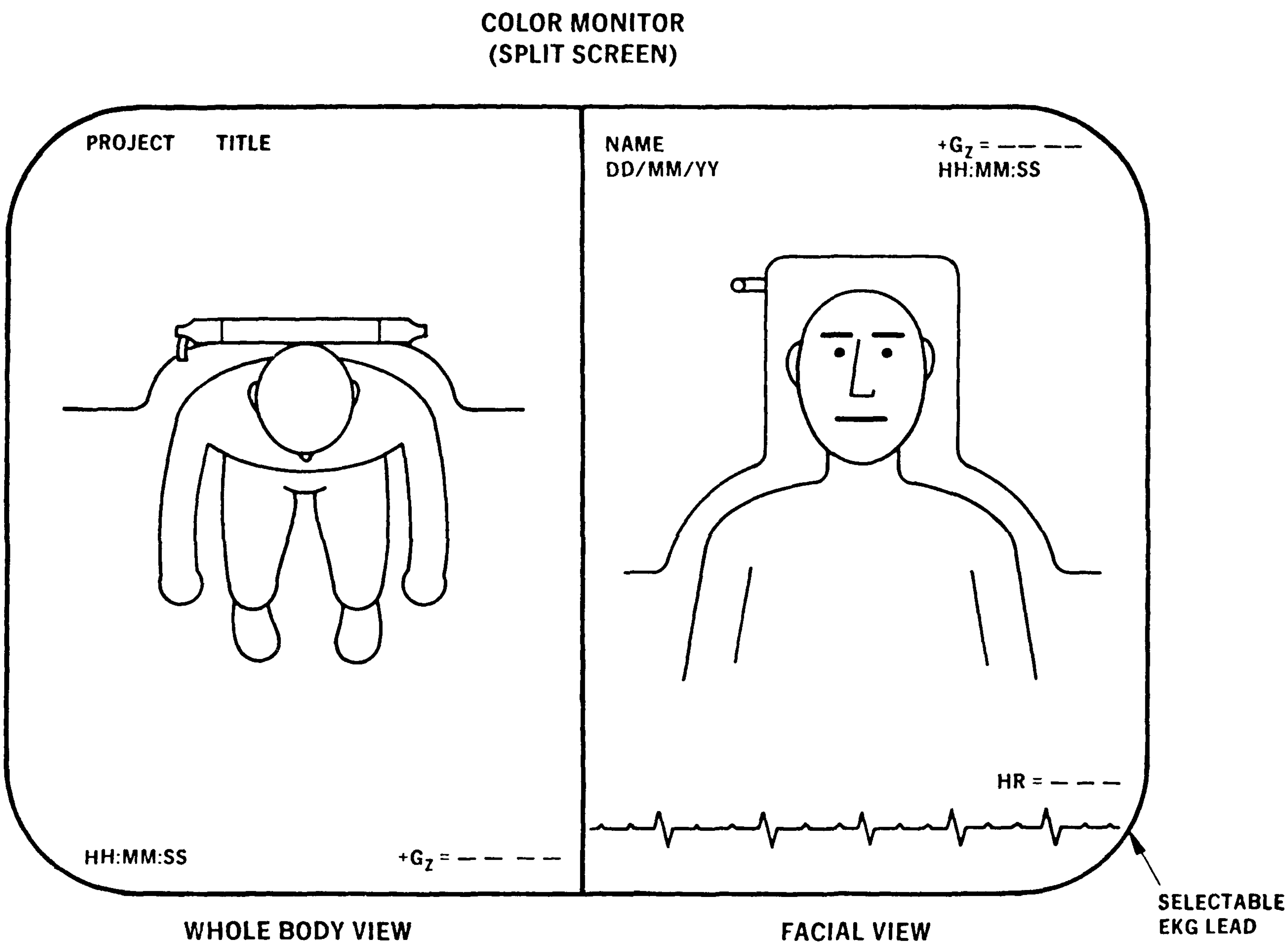

Figure 3. Split Screen Color Monitor Showing Close-Up Of Head and Shoulders View On One Side And Total Body View On The Other Side.

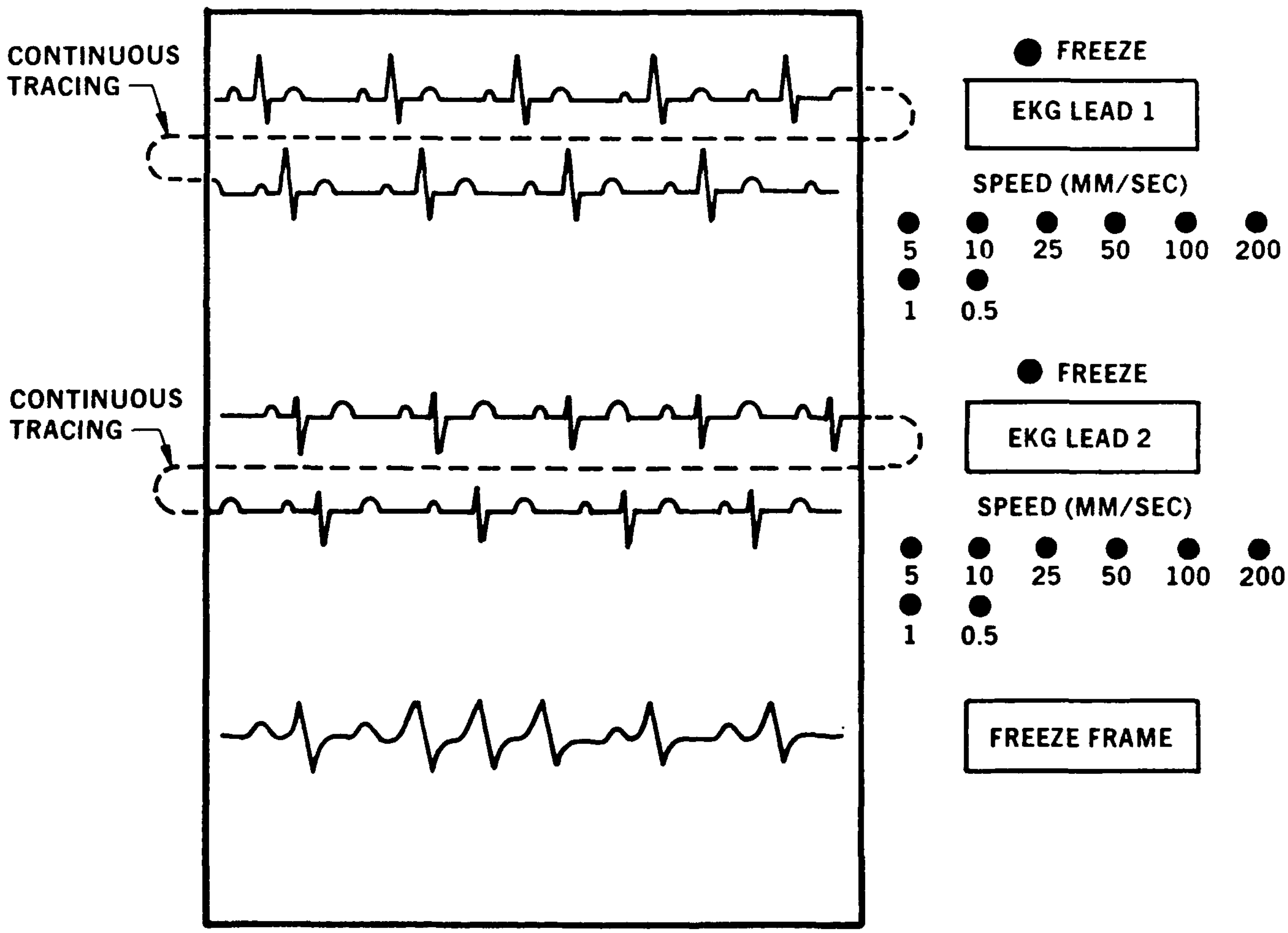

Figure 4. Right Upper Quadrant EKG Oscilloscopic Display With Selectable Freeze Frame Capability.

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