A ROLL IN/ROLL OUT RECONFIGURABLE APPROACH FOR MULTIPLE AIRCRAFT TYPE OPERATIONAL FLIGHT TRAINERS

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ABSTRACT

Operational Flight Trainers (OFT) require a visual system to provide pilot trainees with out-the-window visual cues. Even though the cost of image generation systems has come down in recent years, the cost of a complete visual system with a state-of-the-art dome or collimated cross-cockpit visual display is a significant portion of the total cost of the training device. Using multiple cockpit configurations with a single visual display system can decrease the overall cost of multiple training devices and increase the efficiency of their use.

Under an Air Force contract, a Reconfigurable Operational Flight Trainer (ROFT) was recently developed for the 58th Special Operations Wing at Kirtland Air Force Base in Albuquerque, New Mexico. The design requirement was for a roll in/roll out trainer that would permit more than one device to alternately use the visual display system. The initial device procurement was for a single cockpit, representing a UH-1N helicopter mounted on a moveable platform. The platform contains an Instructor Operating Station (IOS) as well as all necessary equipment and electronics to drive the cockpit instruments and control loading systems. The device was designed to roll into a docked position where a wide-angle (180 x 60 degrees) collimated display system provides visual cueing. When in the docked visual position, the device only needs to be connected to external power and interfaced to the Image Generator to provide full fidelity OFT training. When moved from the docked position to a room corner position, the device is reconnected to external power and used as a stand-alone procedures trainer with high fidelity instrument training capability. In this position another ROFT device could be rolled into the visual docked position for simultaneous full OFT training.

This paper discusses the challenges involved in designing the trainer to fit in a dimensionally constrained room.

Authors' Biographies

Mr. Humphrey is the Engineering Director for Camber Flight Simulation L.C. in Albuquerque, New Mexico. He spent his first nine years in the aerospace industry as a flight test engineer for high performance military aircraft. For the past twenty four years, Mr. Humphrey has worked in the flight trainer industry where he has been involved with the design, development, and testing of high fidelity flight simulators for the U.S. and foreign military. His work has included flight dynamics and project engineering on training devices for the UH-60 Blackhawk, the SH-60 Seahawk, the AH-64 Apache, the AH-1W Cobra, the F-16, and the F-5 Freedom Fighter. Mr. Humphrey has a Bachelor's degree in Aerospace Engineering from Georgia Institute of Technology.

Mr. Maestas is a Senior Mechanical Engineer at Camber Flight Simulation, L.C. in Albuquerque, New Mexico. For the past six years he has been involved with the design and development of systems for the flight simulation, nuclear, and medical industries. In the flight simulation industry, he has worked on the design of structural, flight control, cockpit layout and visual systems for simulators of both fixed and rotary wing aircraft. He has worked on projects for the U.S. and Foreign military including UH-1N, UH-60 Blackhawk, A-4AR Fightinghawk, Bell 212, F-16 and F-5. Mr. Maestas has a Bachelor of Science degree in Mechanical Engineering from the University of New Mexico. He is also President of Tomac Scientific Applications, Ltd., a design services company.

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INTRODUCTION

In September 1997, the USAF awarded a contract to Lockheed Martin and Camber Corporation for a Reconfigurable Operational Flight Trainer, designated “ROFT”. The design concept was for two training devices, representing different aircraft, to alternately share a single visual system. The initial procurement was for a single UH-1N trainer with an option for an additional device in the future. The specification called for a self-contained training device that was reconfigurable by rolling in and out of a visual display station. When docked to the visual station, the ROFT was to operate as a full-mission Operational Flight Trainer (OFT). With the device rolled out of the visual docking station, it was to operate as a Cockpit Procedures Trainer (CPT). Its dual use required the trainer to have self-contained systems including a host processor and an Instructor Operator Station (IOS). The weight and size implications of the self-contained requirements, the field-of-view requirements for the visual display system, and severe dimensional constraints of the training room, created a significant design challenge. This paper describes the UH-1N ROFT system design and the solutions to certain mechanical design problems encountered in the program.

SYSTEM OVERVIEW

Figure 1 shows the reconfigurable part of the trainer. The upper forward section is the trainee station, which is a modified UH-1N helicopter cockpit. The cockpit contains the crew seats, the instrument panel and consoles, and the helicopter flight controls. The rectangular compartment under the cockpit houses the flight control linkages and electric control loading motors which provide the appropriate control feedback to the pilot and copilot. The Instructor Operating Station (IOS) is located on the deck aft of the cockpit and provides controls for setting up and running the training mission. The compartments under the IOS contain the computers, interface linkage, and power supplies that drive both the IOS and crew station instruments and controls. The entire device mounts on four rectangular steel legs. Each leg contains a ball caster that rides on steel tracks embedded in the concrete floor. The IOS platform and electronic equipment bays are generic designs easily adaptable to other types of aircraft simulators. For a follow-on aircraft simulator, which could be a UH-60, V-22, or CH-53, the only new designs needed would be for the cockpit and flight control equipment.

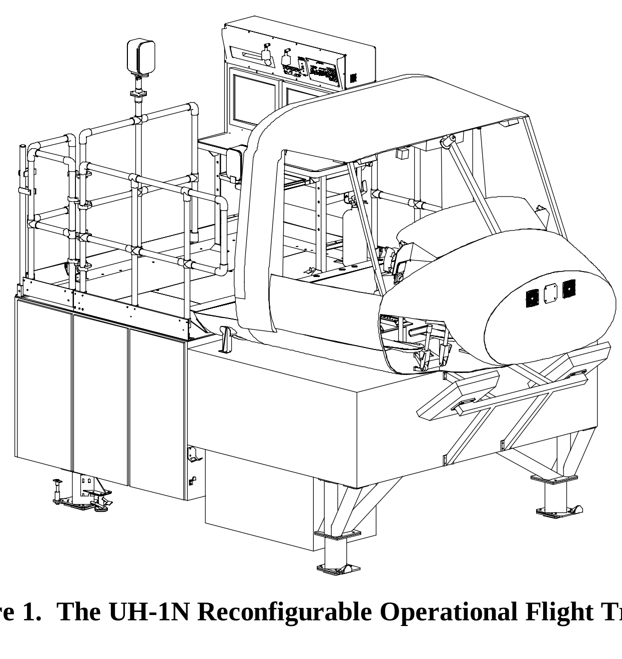

Figure 1. The UH-1N Reconfigurable Operational Flight Trainer

Figure 2 shows the ROFT docking station that supports the Wide Angle Collimated Display (WACD) system. The WACD contains three projectors that beam its video image onto a toroidal-shaped Back Projection Screen (BPS). The screen image is then reflected and collimated by a spherical mirror that has a 180° x 60° field of view (FOV) as seen through the cockpit windows. The system is designed to expand to a 200° x 60° FOV by adding two more projectors. The mirror is primarily a fiberglass structure covered by stretched Mylar that provides the reflective surface. A vacuum system holds the Mylar film to the critical shape of the spherical mirror's primary surface. The WACD was designed, built, installed, and aligned by SEOS Displays Ltd. of West Sussex, England. The visual image projected by the WACD is created by a Lockheed Martin SE 2000 Image Generator (IG) located in a separate room across the hall from the trainer.

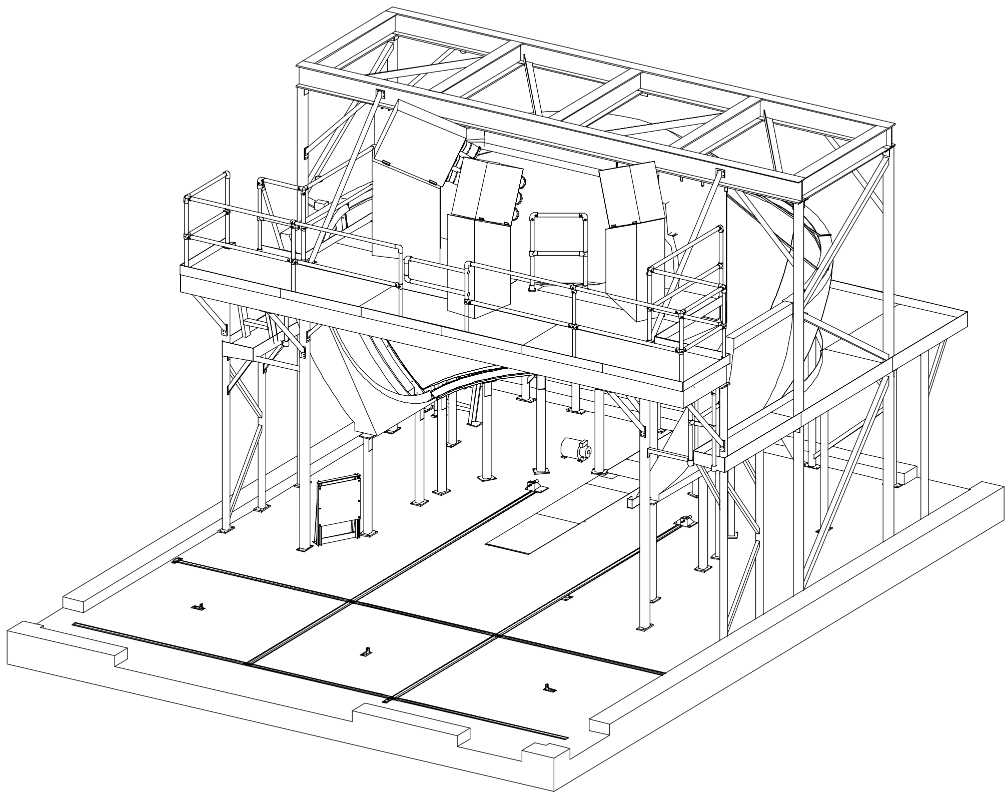

Figure 2. WACD System and Support Structure Docking Station

Figure 3 shows a side, front, and two plan views of the ROFT installed in the trainer facility. The dashed lines show the position of the WACD. One plan view shows the trainer docked in the OFT position that allows full mission training capability including the use of night vision goggles. The other plan view shows the trainer relocated to the room corner for use as a CPT with no visual image. In the CPT position, opaque covers are placed over the cockpit windows to block the external view. The crossed parallel lines in both plan views depict the track system for repositioning the trainer. The severe dimensional constraints within the trainer room are readily apparent from these views. The design challenges created by these and other constraints are discussed in the following paragraphs.

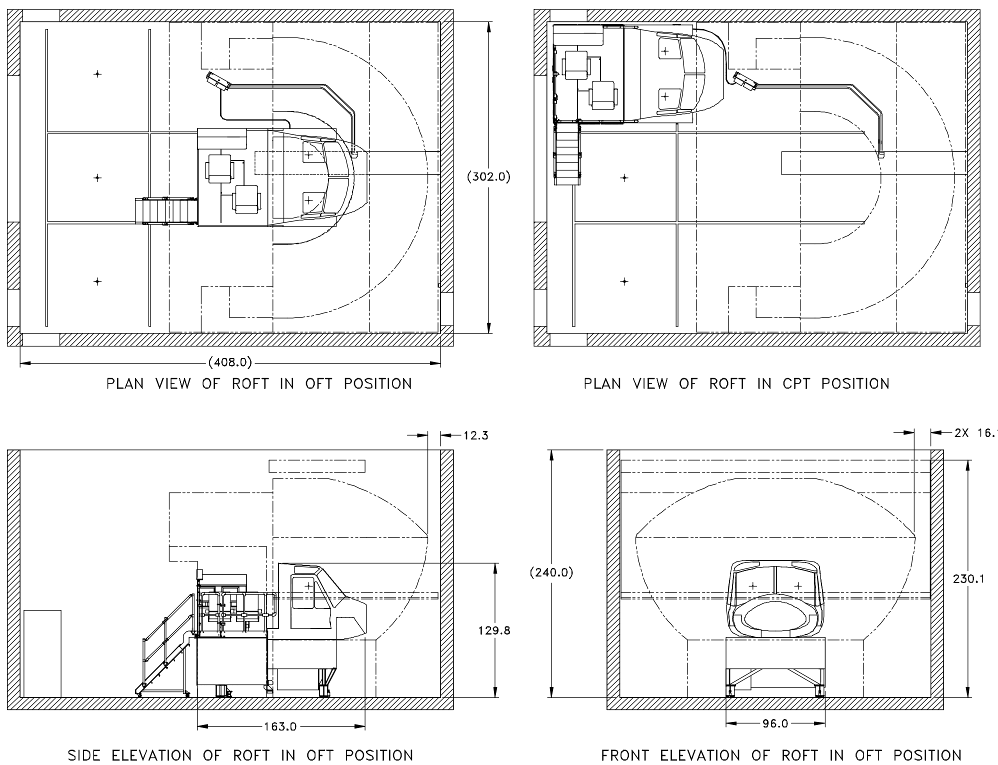

Figure 3. UH-1N ROFT Facility Installation

CONSTRAINTS

The design of the ROFT had to account for many constraints. The entire trainer, except for the Image Generator System, had to fit in the assigned room's dimensions, 25 feet wide, by 34 feet long, by 20 feet high. The contract specified that no part of the trainer or WACD system could be supported by the walls or ceiling.

The installation of the UH-1N trainer had to allow for a second, unspecified, training device to fit into the same room, to share the same visual display system in the same manner, to use a common electrical hookup, and to allow easy maintenance access. Reconfiguration from one device to another was to be performed by no more than two people in under an hour.

DESIGN TOOLS

Many components of the simulator were designed in parallel and required continual feedback among design groups as well as with major equipment vendors. Several software design tools were used to ensure each group's design fit in with the overall system. The primary design package was a parametric CAD system named SolidWorks that generated 3-D solid models from the designs of all parts and subsystems. These solid models could be rotated on screen and were carefully reviewed for proper fit with adjacent parts before manufacturing began. A finite element analysis program was used to double check strengths of components and material selections for critical parts. A kinematics analysis program was also used to check for clearances between moving parts within the trainer, especially in the flight control linkages.

SIZING

The size of the trainer was determined after analyzing the sizes of the room and the WACD and its support structure. Also, several types of aircraft (e.g., V-22, H-60, CH-53) that were likely candidates for a follow-on trainer were analyzed for required flight deck sizes and visual system fields of view. Vertically, a design eye point was determined that would allow each type of aircraft to work with the WACD system as well as provide enough room for the cockpit shell. This position placed the WACD projectors within six inches of the ceiling. Horizontally, the trainer was sized as wide and as long as possible while still giving a minimum of three inches between the walls and a future trainer in any position in the room. For the UH-1N, this analysis determined that fourteen inches of the fuselage's nose had to be cut off. The design left approximately one foot of space around the WACD mirror and the room's walls making a tight but acceptable fit for maintenance access.

PACKAGING

The UH-1N ROFT was packaged in modules to allow reuse of as much of the design as possible for a second trainer. The instructor station and cockpit were mounted on separate frames bolted together to allow the use of the instructor station design for other aircraft types. Reconfiguration-specific equipment (casters, legs, floor locks etc.) was selected to accommodate trainers of varying sizes. The design of the electronic interface panel, mounted under the cockpit base frame, used common component mounts and electrical bus bars with expansion room for a more complex system. All device-specific electronic equipment was placed in the on-board equipment bays. The UH-1N trainer used only five of the six bays.

Electrical connections to the trainer were made through a cluster of four disconnect panels mounted to the trainer room floor. The box that powers the trainer in the OFT position included a separate panel for the visual display signals from the IG. The panels also included connections to the facility's fire detection and emergency power off systems with an override switch so these systems would not be triggered when the trainer is unplugged during reconfiguration.

The trainer and WACD system were designed to allow easy maintenance access to all components of the trainer while in the docked OFT position. The front of each of the six electronic bays can be accessed through hinged doors from outside the trainer. Access to the rear of each bay is through a center rear door into a lighted maintenance space inside the frame. The flight controls and control loading components are accessible through removable panels on the forward base frame and access panels in the cockpit floor. Personnel access to the trainer deck is through a removable staircase connected to the rear of the IOS platform. A built-in ladder and catwalk allow access to the upper deck of the WACD for servicing the projectors and other electronics. A jib-crane is mounted on the upper deck to facilitate raising and lowering heavy equipment.

Alternate access features had to be designed for the CPT position when the rear of the trainer is placed close to a wall. Since the wall blocked the center rear maintenance door, an additional access hatch was designed into the floor of the Instructor Station that opens onto a ladder down to the maintenance space inside the frame. The personnel staircase was made removable and equipped with casters and lock pins to allow it to be repositioned from the rear to the side of the IOS platform.

The two visual display channels through the helicopter's chin windows required a unique design approach. Normally, these types of displays, are achieved by a collimated design involving beam splitters, mirrors, and large CRT monitors. However, the docked OFT position did not allow enough room for a standard design. Instead, a pair of 21-inch flat screen LCD monitors were mounted on a frame fastened to the front of the cockpit base frame and positioned for viewing through the chin windows. These chin window monitors move with the trainer to the CPT position but are not connected to the Image Generator during CPT training.

RECONFIGURATION APPROACH

Initially, the reconfiguration approach was based on using wheeled casters to roll the trainer across the floor when changing between the OFT docking station and the CPT position. However, after the design team completed their sizing activity and fully understood the tight clearances in the trainer room, this approach gave way to designing a track system to safely and repeatedly control the trainer's movement during reconfiguration.

The track had to allow for travel in four directions with 90° intersections and could not be a trip hazard in the darkened room. It also had to be simple to manufacture and install and had to be useable by another trainer sharing the WACD system.

After considering and discarding a track design involving a "V" channel as being too difficult to manufacture and align, the final track configuration consisted of pairs of circular rods embedded flush to the concrete floor with the trainer riding along the rods on four ball casters. The selected ball casters had high load-carrying capacity and low friction and could roll in any direction. To handle two trainers, the pairs of tracks were designed to intersect in a "T" pattern that allowed a trainer to move forward and aft and sideways (see Figure 4). After being moved back from the docked OFT position to the track crossings, the trainer could be rolled to the left for CPT training or to the right for temporary staging during the movement of a second trainer. Stops keep the trainer from running off the ends of the tracks and step-on floor locks secure the trainer in position. A locator pin dropped from the trainer into a hole in the floor ensured the trainer returns each time to the same visual eye point when docked in the OFT position.

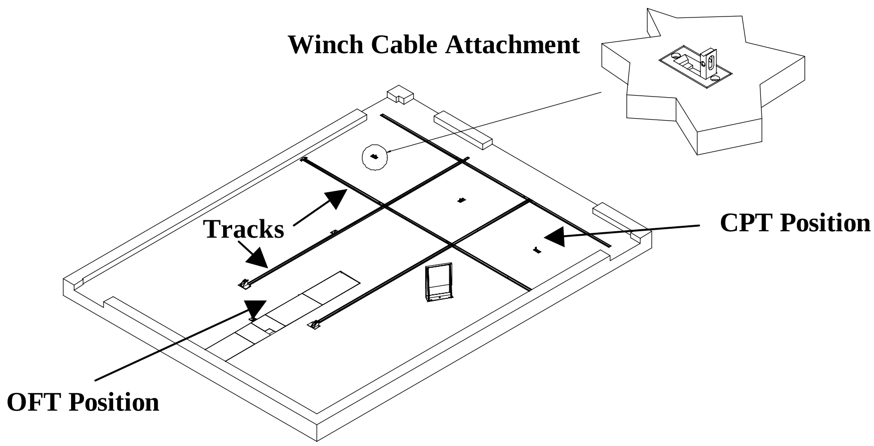

Figure 4. ROFT Reconfiguration Track Layout

To simplify manufacturing, the recessed steel tracks were made from a combination of stock materials (channel, rectangular bar, and round bar) (see Figure 5). The tracks were designed to be assembled using low-strength silicone adhesive. Only the track intersections required machining and welding. Each joint in the tracks used overlapping elements to help distribute the load. The track assemblies were leveled using studs in the floor. The gap between the assemblies and the bottom of the trenches was filled with high-strength epoxy. Temporary spacers ensured that the rails remained parallel and correctly spaced during installation.

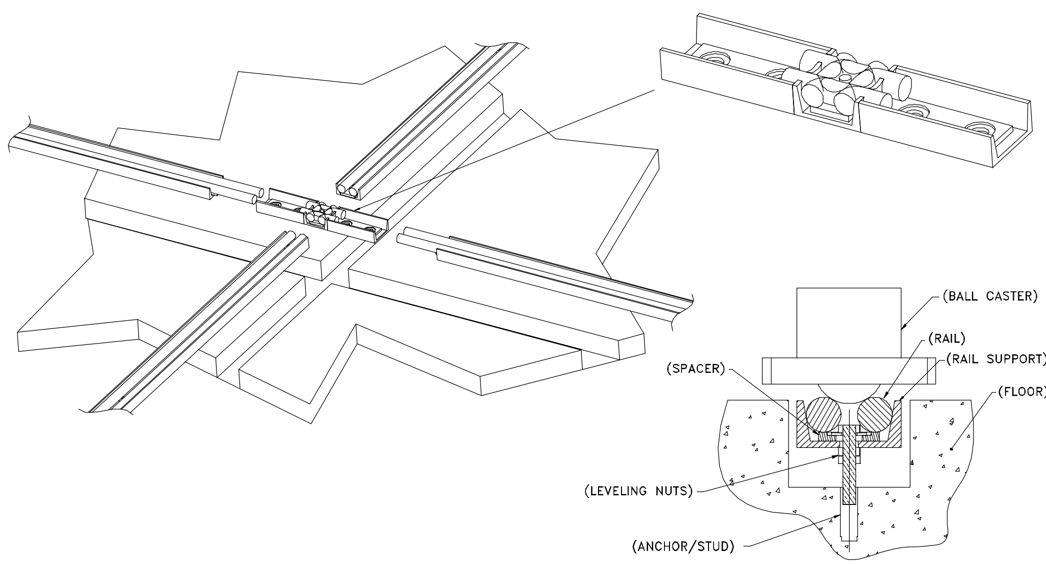

Figure 5. ROFT Reconfiguration Track Design

Due to concerns for being able to move the mass of a trainer weighing nearly 8,000 pounds, a battery-powered winch was installed. The remote-controlled winch was mounted on the bottom of the trainer between the ball casters (see Figure 6). The winch cable was routed through a fairlead so the winch could pull from any direction. As illustrated in Figure 4, flip-up attach points for the winch cable were recessed into the concrete floor.

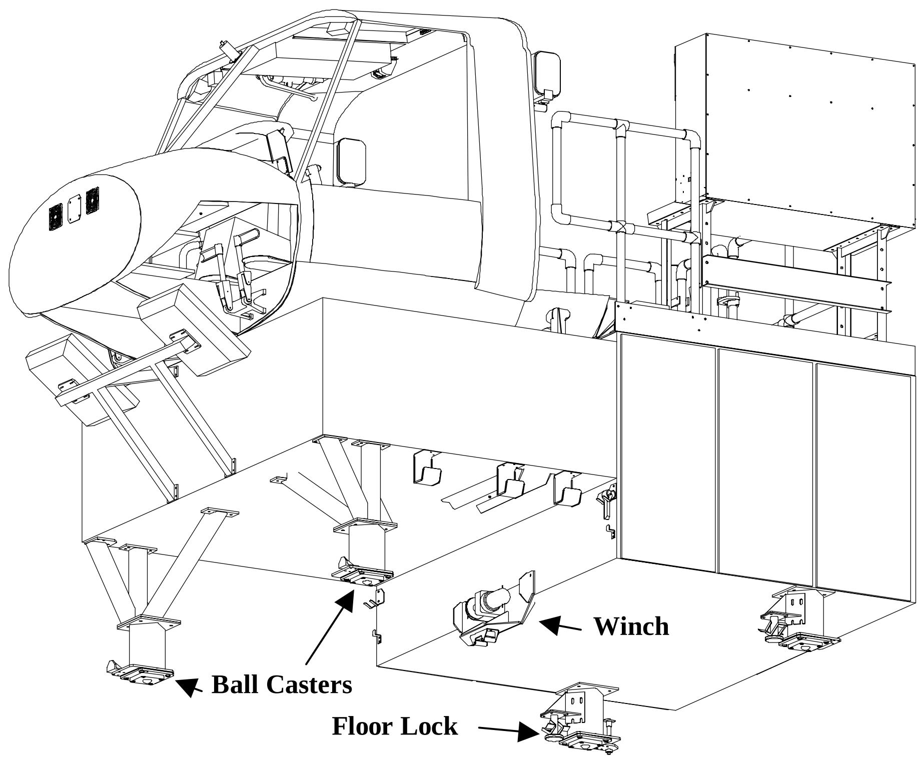

Figure 6. ROFT Reconfiguration Details

CONCLUSIONS

The reconfiguration approach used in the ROFT design was born out of a need for training in more than one aircraft type in a limited size room while providing cost savings from a shared large-field-of-view visual system. These requirements and constraints produced some significant design challenges for the developers especially regarding the roll in/roll out reconfiguring of the device. The simple ball caster system riding a flush-mounted track proved to be safe, easy, repeatable, and more efficient than expected for moving the device. Use of a state-of-the-art solid modeling software tool allowed rapid and accurate sizing and optimal packaging of the design. The modular and expandable IOS and equipment bays proved to be both user and maintenance friendly. The modular design and ball caster track system was expected to help facilitate a low-risk development and integration of a future second reconfigurable trainer.

LESSONS LEARNED

The ROFT development revealed the following observations or lessons learned:

1. The repositioning winch was not necessary because the low-friction ball casters rolling on precision laid and leveled tracks allowed two people to safely and easily push the trainer by hand.

2. State-of-the-art solid modeling software such as SolidWorks was an invaluable tool for developing, sizing, and performing interference analysis of complex systems within tight constraints.

3. System tests revealed that the LCD chin-window monitors could not be conveniently viewed with night vision goggles. When the goggles were manually focussed on the collimated WACD projected display through the forward windows, their focus was not correct for viewing the non-collimated monitors through the chin windows. This condition resulted in the decision to turn off the chin monitors while using night vision goggles. The lack of a visual display through the UH-1N chin windows was not expected to be a major detriment to night vision mission training.