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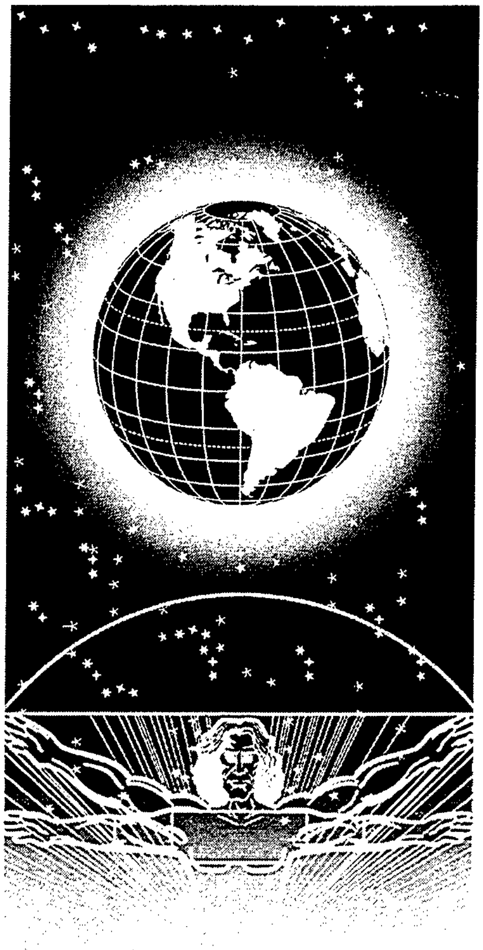

UNITED STATES AIR FORCE RESEARCH LABORATORY

TH-67 SIZE ACCOMMODATION REPORT

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INTERIM REPORT FOR THE PERIOD DECEMBER 2000 TO JUNE 2001

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NOTICES

TECHNICAL REVIEW AND APPROVAL

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public.

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Instruction 40-402.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

MARIS M. VIKMANIS
Chief, Crew System Interface Division
Air Force Research Laboratory

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14. ABSTRACT

This report describes an evaluation of the TH-67 (Bell-Jet Ranger) helicopter. Subjects of widely varying body sizes were tested for: reach to controls, reach to rudder, internal and external vision, body clearances, and control authority. The results indicate that pilots of both small and large size are not accommodated very well in this aircraft.

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BACKGROUND

With the procurement of the Joint Primary Aircraft Training System (JPATS/T-6) and its eventual introduction into the USAF and USN inventories, it will be possible to train pilots whose body sizes are considerably smaller than ever before (Zehner, 1996). The USAF is now considering expanding the body size entrance requirements for Undergraduate Pilot Training (UPT) (AFI 48-123) to take advantage of the increased accommodation offered by the JPATS aircraft and to provide equal access to flight training for both male and female pilot candidates. With current pilot retention problems, the need to expand the pilot corps has taken on additional importance.

In the near future potential USAF pilots will first fly the JPATS and then continue training in either the T-1 Tanker/Transport trainer, the T-38 Fighter/Bomber trainer, or attend Helicopter training with the US Army at Ft. Rucker Alabama. If small or very large pilots cannot safely fly existing trainers, it may be pointless to allow them to enter UPT, and unless these aircraft are modified, there may be no point in designing follow-on aircraft to JPATS-level accommodation limits.

While nearly all USAF aircraft are measured during the procurement process, to determine if an aircraft meets the body size specifications set by the procuring agencies, they are not measured to determine the absolute limits of body size accommodation (Kennedy & Zehner, 1995). We have just completed a research project that quantifies the smallest and largest people that can safely and efficiently operate all of the USAF aircraft now in use.

Currently, the Bell Jet Ranger (designated TH-67 by the US Army) (Figure 1) is part of the training pipeline that all USAF Helicopter pilots must go through. For this reason it was necessary to assess the anthropometric accommodation of the TH-67 cockpit.

Figure 1. The Bell Jet Ranger / TH-67

Our approach relies on the use of numerous test subjects that closely represent the extremes of body sizes within the potential user population. In a sense, we use the subjects as human "tools" to establish the upper and lower limits of body sizes that are able to achieve the operational requirements. Each subject is measured both statically and as they perform a number of functional tasks in the cockpit. We measure excess as well as miss distances. This allows us to calculate minimum and maximum size limits.

We examine the following aspects of anthropometric accommodation:

1. Overhead clearance.
2. Static clearances of the knee, leg, and torso with cockpit structures.
3. Operational leg clearance with cyclic motion envelope.
4. Rotor pedal operation.
5. Internal and external visual field.
6. Hand reach to controls.

Each area will be discussed below.

The seat in this Helicopter is fixed and does not adjust in any direction. While this usually creates blatant accommodation problems, the issues in this case were minor. Overall, we consider the TH-67 to be a rather accommodating aircraft.

EXTERNAL VISION

In some aircraft, external visual field can be so restricted that small pilots cannot see the ground during a landing, or they may have difficulty seeing other aircraft while flying in formation. Some small subjects may experience eye positions below the plane tangent to the top of the glareshield. However, in the TH-67, the main instrument panel is narrower than the cabin width of the aircraft, allowing the pilots to look beside the panel (area A) and down through the chin bubble (area B) shown in Figures 2 and 3. A great deal of external vision in these areas is afforded the crew regardless of size.

Figure 2. Available Visual Area

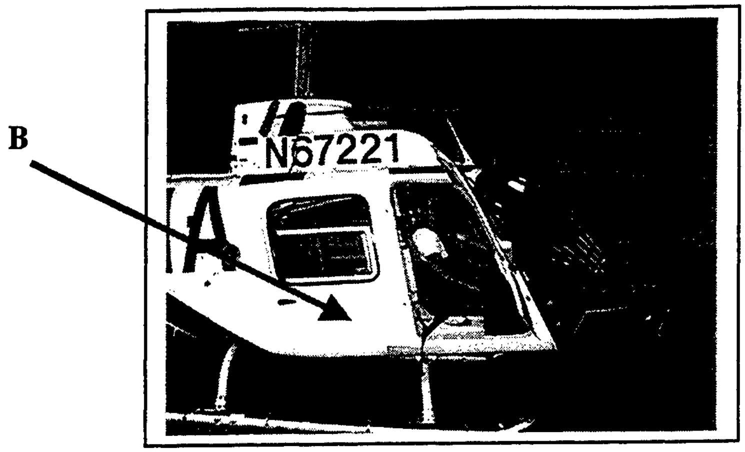

Figure 3. Chin Bubble Visual Area

However, vision directly forward of the pilots is limited for those with short Sitting Eye Heights. Directly in front of the right seat, on the top surface of the glareshield, a moveable structure is used to limit forward vision during instrument training (C, Figure 4). In the stowed position (D, Figure 5), this structure reduces forward over-the-nose vision by 2.5 degrees. These last two and a half degrees equate to a one and a half inch difference in the Minimum Sitting Eye Height needed to see the same forward picture as the left seat pilot.

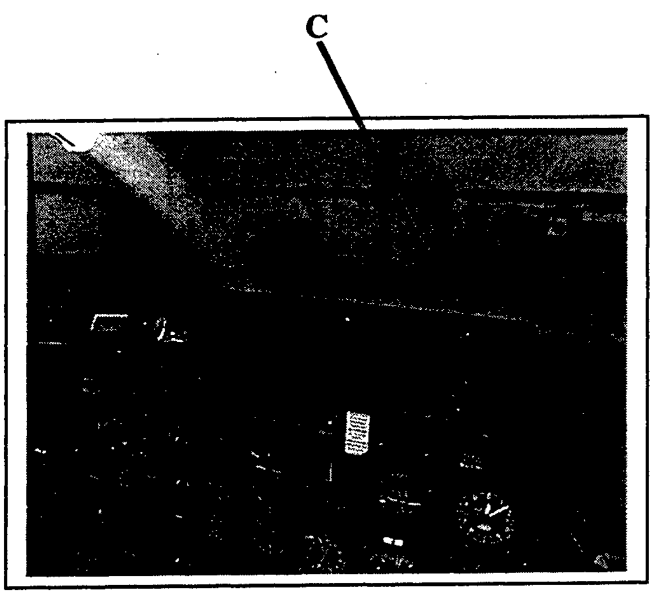

Figure 4. Vision Obstruction Raised

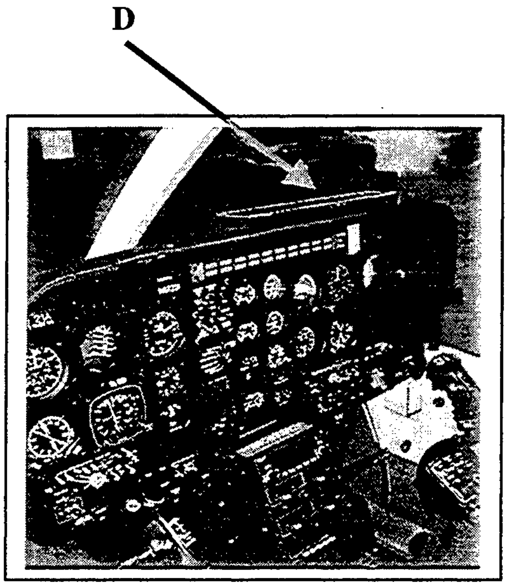

Figure 5. Vision Obstruction Lowered

Vision data gathered on 16 subjects are shown below in Figure 6. The Pearson's r of -.98 (of a possible -1.0) is very high! Vision predictions, given an Eye Height, can be considered very good for this aircraft.

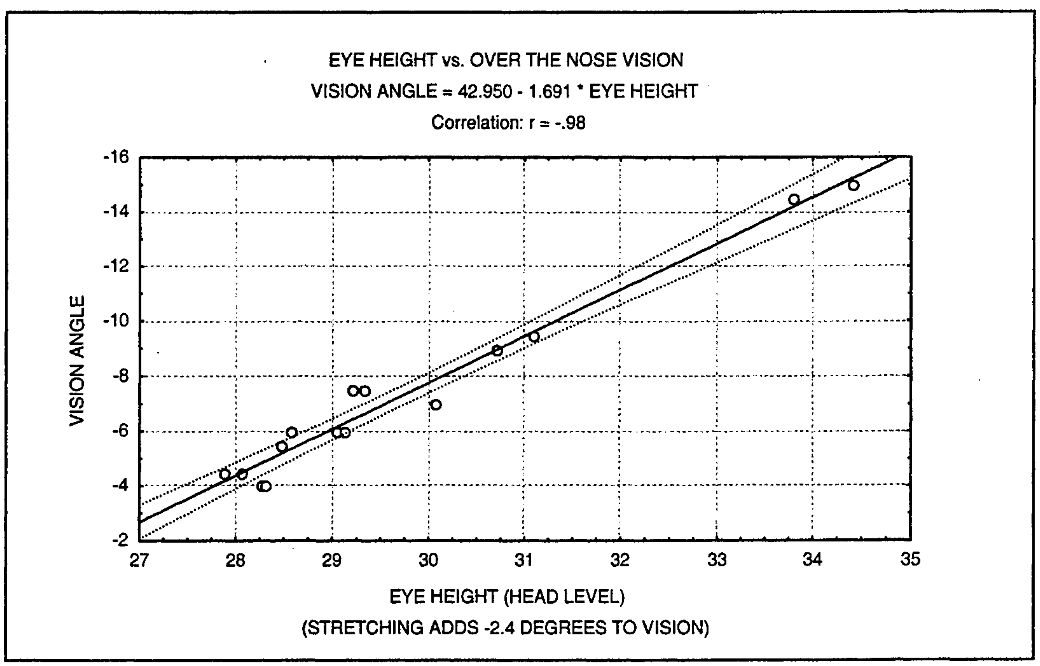

Figure 6. Bivariate of Eye Height and Over the Nose Vision

For the Jet Ranger, we have not been able to locate the original Design Eye vision angle. Data sent by Bell Helicopter do not make sense. Typically, for fixed wing, non-fighter aircraft, -11 degrees is the standard forward vision angle. In the TH-67, this equates to a minimum Eye Height of 31.75 inches. If 1.5 inches were subtracted from this value due to the vision obstruction (D, Figure 5), the minimum Eye Height would be dropped to 30.25 inches – which is very near the 5th percentile male value most older aircraft were designed to accommodate. Stretching the head and neck up adds 2.4 degrees (about 1.5 inches of Eye Height) back to the vision angle. We suspect that pilots below 31.75 inches for Eye Height Sitting are stretching to see directly forward during approaches. We need either verification of the Design Eye vision line from Bell, or, flight test data from pilots below 30 inches in Eye Height to verify this minimum safe size estimate.

REACH TO PEDALS

During heavy crosswinds, full rotor pedal may be required. The measurement which best identifies the minimum leg length required to reach full pedal throw is a combined leg length. We add Buttock-Knee Length and Sitting Knee Height to arrive at a new measure that we call "Comboleg." For example, if a 42" combined leg length is required to obtain full rudder throw, it does not matter if a pilot has a 23" Buttock-Knee Length and a 19" Sitting Knee Height or a 22" Buttock-Knee Length and a 20" Sitting Knee Height. Their reach to the rudder pedals in the TH-67 will be the same. This is only true when the pilot is able to reach full knee extension while pushing the pedal.

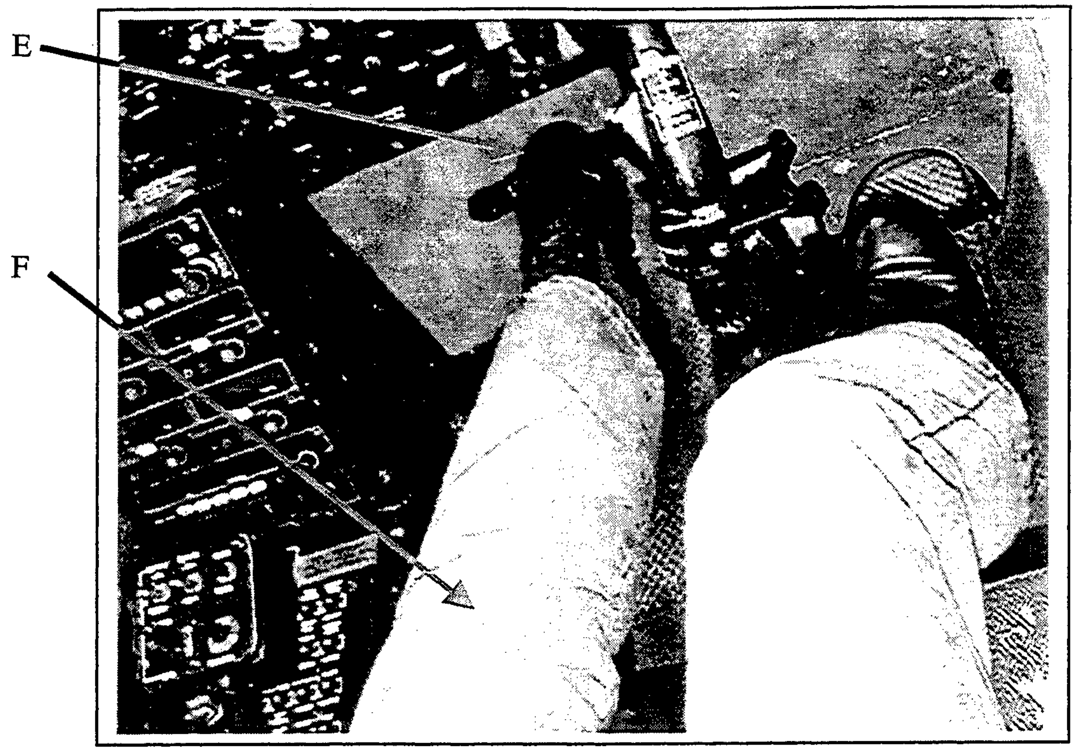

Figure 7. Body posture during Reach to Rotor Pedals

We defined the limit of pedal accommodation as full input with the foot just on the pedal (E) and the knee fully extended (F). The subjects were tightly restrained and not allowed to slide forward in the seat. We then measured subject miss or excess reach to the pedals for regression analysis. The graph below shows miss/excess distance (negative numbers for miss distance, and positive numbers for excess distance) to full pedal for a variety of leg lengths. When positioned this way, a minimum Comboleg length of 39.4 inches is required to attain full rotor pedal in this aircraft.

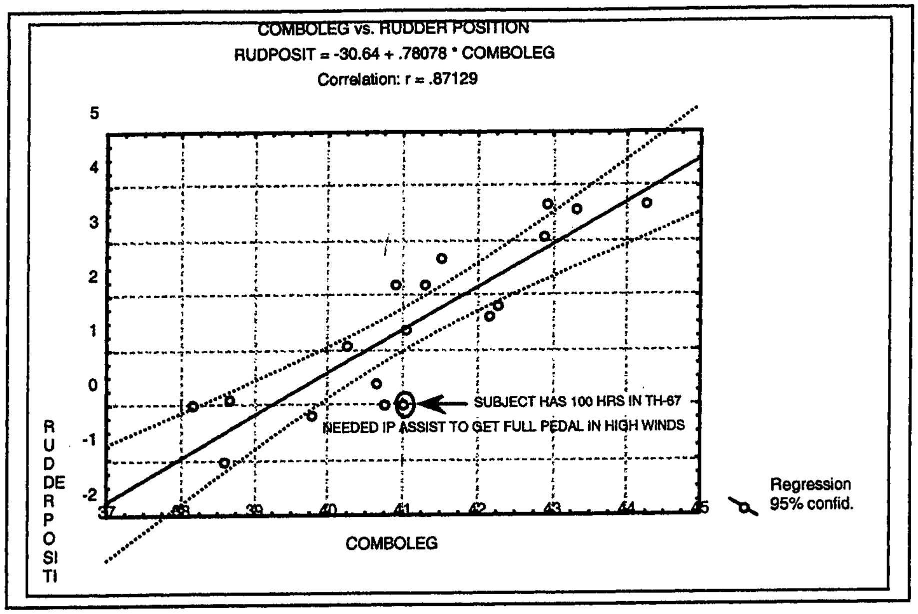

Figure 8. Bivariate of Comboleg and Reach to Rotor Pedals

Notice the circled subject in the graph above. This individual has 100 hours in the TH-67 and falls below the line we predict by 1.25 inches. This person put her foot more fully on the pedal than in the Figure 7 illustration. Foot position can make up to two inches difference in the graph above. Also, she told us that an IP had to assist her to get full pedal during a heavy cross wind situation. A Comboleg of 39.4 inches may be too liberal an interpretation of the position of the foot and leg for adequate control of the pedals. A two-inch safety margin would yield a minimum Comboleg of 41.4 inches.

ARM REACH TO CONTROLS

Pilots must be able to reach and operate hand controls to safely fly an aircraft. In normal flight conditions, with the inertia reels unlocked, this is usually not a difficult task. Under adverse conditions, however, or when there is an inadvertent reel lockup, small pilots will have difficulty reaching many controls. Inadvertent reel locks happen in aircraft as much as they do for some automobile seat belts. Turbulence or rapid movements can cause the mechanism to lock up. But unlike an automobile, the aircraft pilot must flip a switch on the front edge of the seat to release the mechanism. Until that is done, the pilot's movements are very restricted. Several factors other than body size affect reach capability in an aircraft cockpit. The design, fit, and adjustment of harnesses, personal protective equipment, survival gear, body strength, and motivation, all influence the ability to reach. Due to these factors, reach is the most difficult area of accommodation to accurately quantify. In this study, reach to controls was based upon two harness configurations: first, with the reels locked but with a maximum stretch toward the control, and second, with the reels unlocked.

Arm Span is the measurement used to predict reach capability. It has the highest correlation with reach results and is the easiest of many arm measurements to replicate. Surprisingly, with unlocked harnesses, every subject could reach every control except one, and she missed only one control. She had an Arm Span of just under 60 inches. The control that was missed is duplicated on the right side of the cockpit.

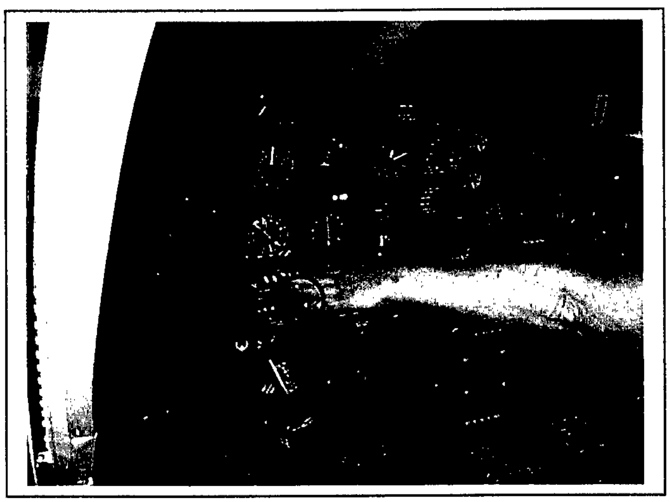

Figure 9. Zone three reach – missed area

Thus, reach unlocked is not a problem for people with a 60-inch Arm Span (2^{nd} percentile military female) or greater.

With locked reels, all subjects could reach everything on the overhead panel, as well as the Circuit breakers and light rheostats on the center panel (between the seats). Collective and Cyclic reaches were easily accomplished. However, the forward panel and the radios just below it are much more difficult to reach. Figures 10 through 12 summarize the reach capability of different size people. The areas inside the green box and the highlighted knobs are reachable.

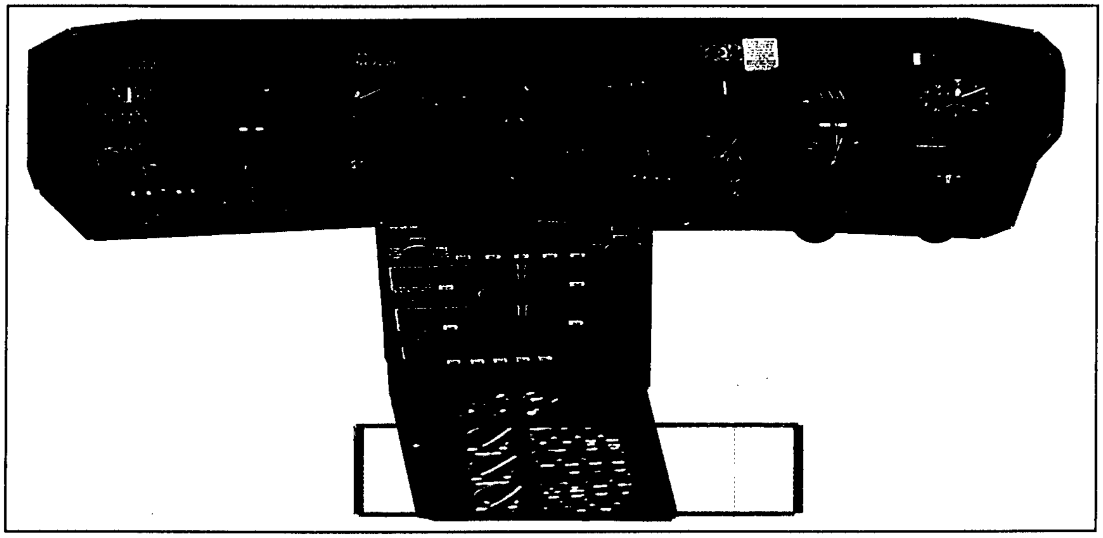

Figure 10. Areas accessible to Subjects 60"- 62" for Arm Span (locked reels)

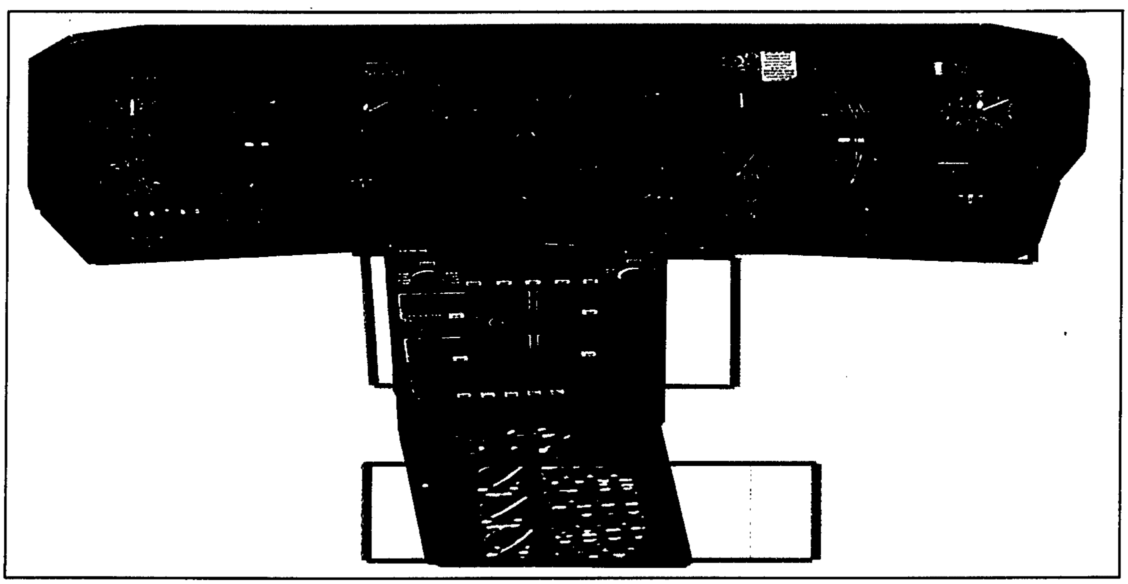

Figure 11. Areas accessible to Subjects 62" - 64" for Arm Span (locked reels)

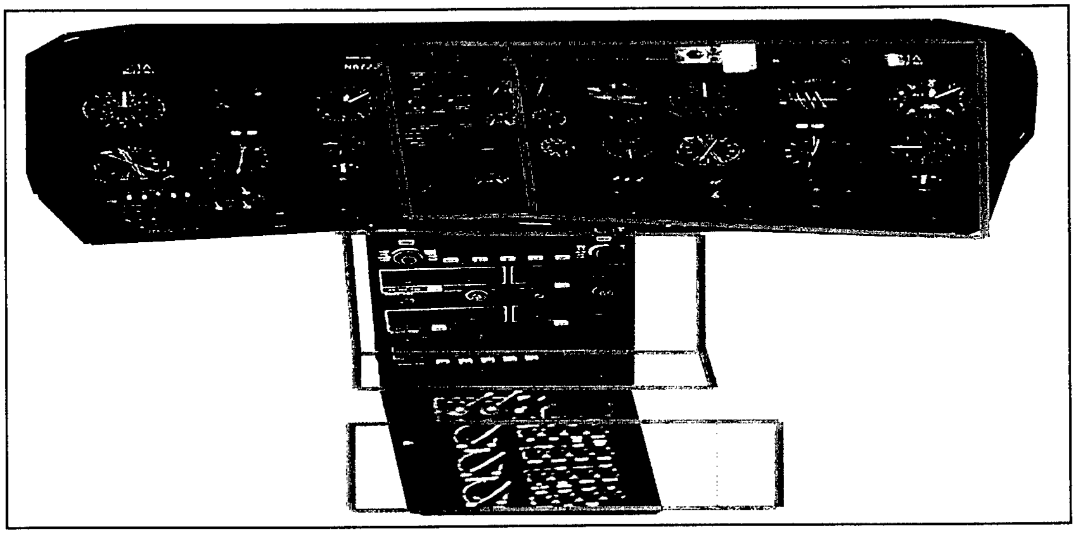

Figure 12. Areas accessible to Subjects 64" - 66" for Arm Span (locked reels)

A pertinent question can be raised: Which if any of these controls are needed during an emergency when the reels may have been locked (even if inadvertently)? Our discussions with Instructor Pilots at Ft. Rucker suggest that they never intentionally lock their reels unless a crash is imminent. In that situation only the Cyclic, Collective, and Pedals are needed. The Harness Inertial Reel Lock would also need to be reached in case of an inadvertent lock. None of these controls would be difficult to reach for people with as small as a 60" Arm Span.

OVERHEAD CLEARANCE

There is not enough overhead clearance space in the TH-67. Tall torso pilots will be forced to assume a slouched posture, or should not be assigned to this aircraft. Maximum Bareheaded Sitting Height (head hits the structure overhead) is 41.2" directly overhead, and 40.2" to the molding down the center of the overhead panel. If wearing the current Army helmet, the numbers are reduced 1" overhead, and .8" to the center molding (resulting in 40.2 and 39.4 inches respectively). I will not recommend that the USAF waiver pilots larger than 40 inches in Sitting Height to fly the TH-67. This aircraft is equipped with a down stroking crashworthy seat. If possible, pilots must be able to assume an erect spine posture prior to crash. A slouched posture could result in severe spinal injuries during a crash.

SHIN CLEARANCE WITH THE MAIN INSTRUMENT PANEL

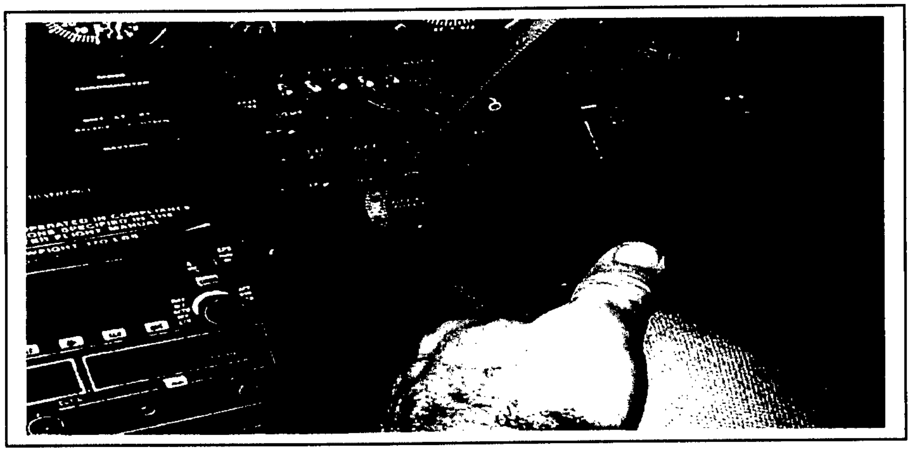

Figure 13. Shin Clearance

Shin clearance is adequate in the TH-67. However, Buttock-Knee lengths greater than 27.9" will be in contact with the lower edge of the main instrument panel or the vent knob (indicated by the arrow).

CYCLIC CLEARANCE WITH THE THIGHS

There is some interference between the Cyclic and the Knee of large legged pilots. This is particularly true in the right seat, at about the *neutral pitch - rolled full right* position. Everyone we tested could move around to avoid this contact, however. The hand rest on the cyclic grip is the culprit here. It acts like a knife blade stabbing pilots in the knee. Large pilots should be sure to test the cyclic range of motion prior to flying this aircraft. The amount of interference is reasonably small. The illustration below is from the T-3A.

Figure 14. Pilot's knee trapped between Stick and Throttle (T-3A)

In the left photo (Figure 14), an attempt is shown at Full left stick with neutral rudders, and again, in the right photo, with full left rudder input. Notice the difference in the length of the arrows. The TH-67, however, does not have a problem this severe.

SUMMARY

There are two accommodation problem areas in the TH-67. Overhead clearance for tall pilots, and Over the Nose vision for short pilots. We cannot recommend that USAF pilot candidates larger than the current USAF Sitting Height limit of 40 inches be allowed to fly this aircraft. To do so places them at increased risk of injury in case of a crash. A Maximum Buttock-knee length of 27.9" is recommended (this is larger than the USAF primary trainer).

For small pilot candidates, the minimum values for Sitting Eye Height should be 30" until flight tests demonstrate that less vision over the nose is acceptable. Anecdotal evidence of small pilots having trouble seeing in approaches is not solid, but serious enough that we should not send small-torso pilots to this aircraft. Forward vision could be easily improved by replacing the vision blocking device on the right side glareshield with something that can be completely stowed.

Based on the difficulty our experienced TH-67 pilot had, Minimum Comboleg should be 41.4". This is not the leg-length bottleneck for USAF helicopter pilot candidates. The MH-53J requires a 43.5" Comboleg.

Arm reach to controls is not a problem with this aircraft. A 60" Arm Span will be the minimum recommendation because of reach to the fuel switch with locked reels. This Arm Span value is also not a reach bottleneck.

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