TEST PILOT EVALUATION OF A RECLINED COCKPIT SEAT AS AN AID TO G TOLERANCE AND PERFORMANCE

AEROSPACE MEDICAL RESEARCH LABORATORY

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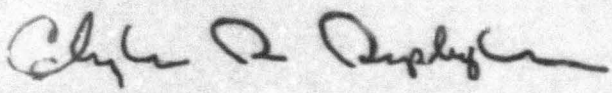

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Twenty-two student test pilots have participated in closed-loop tracking indoctrination runs on the Dynamic Environment Simulator. Each pilot flew through a series of profiles up to 6 G in both the conventional upright seat position and a 55° tilt back seat position. The subjective responses and pilot questionaires are presented.

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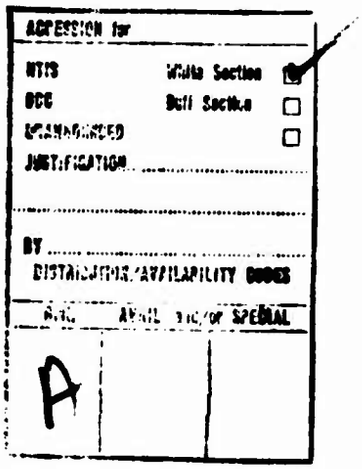
PREFACE

The evaluations reported herein were conducted by the Aerospace Medical Research Laboratory, Environmental Medicine Division, Dynamic Simulation Branch, in September 1973 and March 1975 as part of a continuing development of the High Acceleration Cockpit (HAC) as a viable and effective concept for future fighter aircraft. The work was conducted under project 7222, task 10, Pilot Performance in High Agility Aircraft. A total of 22 USAF and USN test pilots participated in the evaluation of the effects of normal G stress and seat back angle upon pilot performance in flying a simulated aircraft.



INTRODUCTION

The increasing capability of fighter aircraft to perform sustained high acceleration (G) turns will soon exceed that of a human pilot to function effectively. If such high G maneuvering will provide a tactical advantage, then the human G tolerance must by some means be increased.

Currently, the anti-G suit serves as the only G protection device. It consists of a system of inflatable leg and abdomen bladders which, when filled, apply pressure to those areas and assist the circulatory system in maintaining an adequate blood supply to the upper body. The anti-G suit is a proven and valuable aid. However, even with this assistance human tolerance to sustained acceleration is limited to about 8 Gz.

Another concept to raise man's G tolerance is to put him in a more supine position, rather than the conventional 13° upright position. Centrifuge studies using human subjects have verified that both man's blackout tolerance and his performance of a flying tracking task can be improved by increasing the angle of the seat back beyond 45°. This positioning reduces the loss of blood flow and pressure to the head resulting from the high maneuvering G.

The USAF Flight Dynamics Laboratory is proceeding on an Advanced Development Program, called the High Acceleration Cockpit (HAC), to construct and fly a demonstrator fighter cockpit with a supinating seat. In order to gather subjective data from operational pilots relating to the supinating seat concept, two groups of USAF and USN test pilots from Edwards AFB were run on the AMRL Dynamic Environment Simulator (DES). One group of 11 was given familiarization runs in September 1973 and another group of 11 in March 1975.

DESCRIPTION OF DES FAMILIARIZATIONS

The first group of 11 pilots (Sep 73) was run using a supinating seat developed in house at AMRL for HAC validation experiments. The DES was controlled by the test pilot subjects through a displacement type side arm controller to simulate actual aircraft G response to a pitch command input. They were instructed to fly the DES using a G meter, through a G vs time profile as follows:

Each G level was held for 30 seconds. Each pilot flew the profile twice: once in the 13° (upright) seat back position, and once in a 55° supinated position.

*(DES), a centrifuge with three degrees of freedom, an aircraft cockpit simulation in the gondola, and closed loop control by the pilot.

The second group of test pilots (Mar 75) was given runs on the McDonnell-Douglas HAC seat with a sidearm force stick controller. This seat was more representative of an actual aircraft seat than the previous one. In addition, a video display presented to the pilot an actual air-to-air combat tracking task with the following profile:

The profile was flown four times by each pilot, once each at peak G levels of 4 and 6 G, with a seat back angle of 20°. The 4 and 6 G runs were then repeated with a seat back angle of 55°.

In both of the above series of tests, the pressure in the anti-G suit for the 55° seat back position was reduced from the normal upright pressure schedule following the method of reference 1. All subject pilots in both series of runs were administered questionnaires after their runs to gather their subjective comments and observations regarding the HAC concept. No attempt was made to evaluate their tracking performance during these familiarization runs.

RESULTS

The questionnaires and the pilots' responses are contained in Appendix A. The comments may be summarized as follows:

1. The pilots had all previously been made aware, through briefings or static demonstrations, of the anticipated benefits of a supinating seat during high G flight maneuvers.

2. The AMRL HAC indoctrination was of personal benefit to the pilots in three ways: First, the advantages of the reclining seat concept were vividly demonstrated: Greater G tolerance, less fatigue, and improved pilot performance capabilities. Second, it was an opportunity for them to evaluate their own reactions and capabilities under sustained G loading, in circumstances other than actual flight. Third, most of the pilots received their first exposure to a sidearm controller, and its benefits under high G conditions were made apparent.

3. In subjective comparisons of the 20° and 55° seats, the pilots unanimously reported that the 55° seat allowed for greater blackout tolerance, less straining to maintain vision, reduced fatigue, and easier accomplishment of cockpit duties. However, two pilots experienced chest pains or difficulties in breathing at 55°, common phenomena among past centrifuge subjects. These symptoms can normally be expected to be relieved by adjusting one's breathing patterns toward short, shallow breaths.

4. The pilots as a group reported that they would anticipate an additional 2 G of useful sustained acceleration tolerance resulting from the reclining seat concept, if implemented in a fighter aircraft.

5. The pilots in the second group, when questioned concerning their usual personal methods of G protection, reported that the most favored and beneficial methods in an upright seat were the anti-G suit and muscular tensing. The M-1 breathing/straining maneuver was less preferred, and a small number occasionally made use of such methods as crouching forward in their seats or screaming to improve G tolerance.

6. The comments regarding the reduced anti-G suit pressure indicated that it was acceptable, or that they were not aware that it had been reduced.

APPENDIX A

24 September 1973 **PILOT #1**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?

   Yes

2. Was this indoctrination of any benefit?

   It showed me that the seat does increase the G tolerance.

3. Could you compare the two positions: (i.e., comfort, grayout, straining required etc.)?

   13° — At 4.5 — 5 indicated G a grayout started.

   55° — Went to 6 indicated G with no grayout.

4. What if the G levels had been higher — i.e., 10 G?

   I could go to about 7 indicated G before grayout. My tolerance is 4 G's in an aircraft with no G-suit.

5. Other comments?

24 September 1973 **PILOT #2**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?

   Yes

2. Was this indoctrination of any benefit?

   Yes

3. Could you compare the two positions: (i.e., comfort, grayout, straining required etc.)?

   Main apparent difference was that M—1 maneuver was 1) not very necessary and 2) almost no effect in the 55° position. Which of these was noticed first, I'm not sure.

4. What if the G levels had been higher — i.e., 10G?

   I would not volunteer, unless it was a prerequisite to a job I wanted.

5. Other comments?

   Very interesting.

23 September 1973 **PILOT #3**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?

   Yes

2. Was this indoctrination of any benefit?

   Yes

3. Could you compare the two positions: (i.e., comfort, grayout, straining required etc.)?

   13° — No grayout, much strain required, hard to talk.

   55° — No grayout, less strain required, harder to breathe, easier to talk.

4. What if the G levels had been higher — i.e., 10 G?

   Easier in 55° position.

5. Other comments?

   Thanks

24 September 1973 **PILOT #4**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?

   Yes

2. Was this indoctrination of any benefit?

   Yes — transverse G's — now I know more of what to expect in a cockpit with reclined seat — high G.

3. Could you compare the two positions (i.e., comfort, grayout, straining required, etc.)?

   13° — Rather standard — no grayout — slight M—1 at 5G reading.

   55° — Quite comfortable — no grayout — no real straining required.

4. What if the G levels had been higher; i.e., 10G?

   55° much more tolerable.

5. Other comments?

24 September 1973 **PILOT #5**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?

   Yes

2. Was this indoctrination of any benefit?

   Yes — the introduction was enough to stimulate thought on interest points. No comments can be made about differences without another look.

3. Could you compare the two positions (i.e., comfort, grayout, straining required, etc.)?

   13° — less comfortable at high G

   55° — pitch sensation seemed greater with the acceleration and deceleration.

4. What if the G levels had been higher; i.e., 10 G?

   Differentiation might have been larger and more evident.

5. Other comments?

24 September 1973 **PILOT #6**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?

   Yes

2. Was this indoctrination of any benefit?

   Yes, it indicates definite possible improvements to crew G tolerance.

3. Could you compare the two positions (i.e., comfort, grayout, straining required, etc.)?

   13° — Required some straining to reduce tendency toward tunnel vision. Limited head movement capability at 5 G's.

   55° — Definite improvement, particularly in head movement (look-around) capability at high G.

4. What if the G levels had been higher; i.e., 10 G?

   Probably would have experienced more noticeable differences between the 2 seat positions.

5. Other comments?

   G onset too low to simulate actual aircraft flight conditions.

25 September 1973 **PILOT #7**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?

   Yes . . . more so now!

2. Was this indoctrination of any benefit?

   Certainly.

3. Could you compare the two positions (i.e., comfort, grayout, straining required, etc.)?

   13° —More comfortable for instrument scan and "normal" flight (+2 G's). Had to puff a little at 5 G's to "keep the gray away."

   55° — Definitely more comfortable under G loads. No sense of impending grayout up to 6 G!

4. What if the G levels had been higher; i.e., 10G?

   No way upright — felt I could have at least reached it, if not sustained it in supine position.

5. Other comments?

   Training required to find an optimum position. There are certainly tradeoffs between the two positions. Also, the muscles affected by G-loads are different for the two positions. Might have to modify G-suits so they don't *hurt*.

25 September 1973 **PILOT #8**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?

   Yes

2. Was this indoctrination of any benefit?

   Yes

3. Could you compare the two positions (i.e., comfort, grayout, straining required, etc.)?

   13° — 3 G increased weight effects

   4 G tunnel vision initiated
   approximately 1/2 field affected

   5 G increase of grayout
   approximately 90% field affected — grunt mainly used

   55° — 3 G increased weight effects

   4 G tunnel vision initiated (approximately 10% affected)

   5 G increase of grayout (approximately 50% affected) uncomfortable, arm fell off arm rest used grunt mainly 1/2 time for comfort.

4. What if the G levels had been higher; i.e., 10 G?

   Expect blackout.

5. Other comments?

   Left arm rest should be at similar height. Need some restraining device on arm rest to preclude arm from falling off with increasing G.

25 September 1973 **PILOT #9**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?
   Yes
2. Was this indoctrination of any benefit?
   Yes
3. Could you compare the two positions (i.e., comfort, grayout, straining required, etc.)?
   13° — Straining
   55° — Comfortable
4. What if the G levels had been higher; i.e., 10 G?
   I feel that I could go to a higher G-level, but I cannot say anything about 10 G.
5. Other comments?

25 September 1973 **PILOT #10**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?
   Yes
2. Was this indoctrination of any benefit?
   Yes
3. Could you compare the two positions (i.e., comfort, grayout, straining required, etc.)?
   13° — Straining, some Gray
   55° — Comfortable
4. What if the G levels had been higher; i.e., 10 G?
   Hard to say without trying.
5. Other comments?
   Beneficial. The G tolerance improvement is very noticeable.

25 September 1973 **PILOT #11**

1. Are you aware of human tolerance levels to acceleration in the upright and supine positions?

   Yes

2. Was this indoctrination of any benefit?

   Yes

3. Could you compare the two positions (i.e., comfort, grayout, straining required, etc.)?

   13° —

   55° -- More resistance to grayout — less straining but perhaps a little more breathing problem.

4. What if the g levels had been higher; i.e., 10G?

   55° should allow you to go 10.

5. Other comments?

3 March 1973 **PILOT #12**

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Yes — but I had never had an opportunity to actually experience it.

2. Was this indoctrination any benefit to you? If so, in what way?

   Yes — for the reason stated above and for the side stick controller experience.

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required, etc.)?

   20° — 6 G's require considerable straining to avoid grayout. Strain in shoulders, upper arms, neck.

   55° — Much more comfortable, almost no grayout (with proper anticipation), less straining. Chest forces are distracting but not overbearing.

4. What if the G levels had been higher (e.g., 8—10G)?

   I think the trend would have been the same. However, the increased chest forces might become uncomfortable to a distracting point.

5. What G-Protective technique do you normally use at high G?

   G suit, M—1 Straining, and Muscle tensing.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout; pressure too high, too low or about right etc.)?

   Pressure increase or onset could have been started a little sooner. Protection against grayout is helpful, however I was already straining fairly hard before the G-suit inflated.

7. Any other comments?

   Super ride — thanks.

3 March 1975

PILOT #13

1. Prior to today's indoctrination runs, had you been awa·e of the effect of seat back angle on human tolerance to acceleration?

   Yes, by briefing.

2. Was this indoctrination of any benefit to you? If so, in what way?

   Yes. It helped me to be more observant and be able to understand my experience today.

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required, etc.).

   20° — More straining required at 6G than in the 55° seat.

   4 G — not too much difference (straining, grayout).

   55° — More comfort at all G's. Most significant to me was not having to hold my head steady under the load, especially at 6G.

4. What if the G levels had been higher (e.g., 8—10G)?

   I feel the 55° seat would have allowed me to go to the 8—10G level, whereas the 20° seat would have allowed only 1—2 more G (7—8G).

5. What G-Protective technique do you normally use at high G?

   G-Suit, M—1 Straining and Muscle tensing.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout; pressure too high, too low or about right etc.)?

   Sufficient.

7. Any other comments?

   No.

3 March 1975

PILOT #14

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Yes. Had participated in the static HAC evaluation at Edwards October 1974.

2. Was this indoctrination of any benefit to you? If so, in what way?

   Only that I knew the reclined seat was very comfortable.

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required, etc.)?

   20° — Grayout controllable through flexing of stomach muscles.
   Tingling in toes and calves after 20 sec at 6 G.

   55° — Definitely more comfortable; less tendency toward grayout. Slight ache under breastbone after about 10 secs at 6 G.

4. What if the G levels had been higher (e.g., 8—10G)?

   Feel I could have handled 7.5 — 8.0G at 20°, and 10+ at 55°.

5. What G-Protective technique do you normally use at high G?

   G-Suit, Muscle tensing and Crouching.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout; pressure too high, too low or about right etc.)?

   I like the pressure where it is through flexing of stomach, one could probably handle 6.0G at 55° tilt with no pressure at all.

7. Any other comments?

   The side force stick and tilt seat are definitely the way to go in combat aircraft design.

3 March 1975

PILOT #15

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Yes. Briefings and films.

2. Was this indoctrination of any benefit to you? If so, in what way?

   Yes. I knew to expect better G tolerance and that I would be somewhat more comfortable at higher G.

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required. etc.).

   20° —

   55° — Better, more comfortable in every case.

4. What if the G levels had been higher (e.g., 8—10G)?

   — unable to track at higher G with the 20° seat. For me probably 6 — 6.5 G would have been the max I could have tolerated and still tracked the target.

   — 6 G was easy with the tilted seat. Probably 7 — 7.5 would be optimum for tracking.

5. What G-Protective technique do you normally use at high G?

   G-Suit and Muscle tensing.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout pressure too high, too low or about right etc.)?

   When erect the G-suit gave me pressure in the lower abdomen — not there in the reclined position.

7. Any other comments?

   — I think it is notable that in the 6-g tracking maneuver in the reclined position the pilot can still talk where he cannot do this too well while vertical; e.g., he could still talk to a wing man.

3 March 1975

PILOT #16

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Through briefings on the HAC only.

2. Was this indoctrination of any benefit to you? If so, in what way?

   Yes, it gave me some idea of my own reactions to sustained "G."

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required, etc.)?

   20° — Quite comfortable at lower G levels; however, at the higher levels it was difficult to concentrate on the tracking task due to the amount of straining required. Lower extremities were particularly "tingly." Small amount of grayout.

   55° — Less comfortable at lower G levels but considerably less strain required at higher levels. Chest pains associated at highest "G" level.

4. What if the G levels had been higher (e.g., 8—10G)?

   I don't think I could have handled them in the 20° seat, but quite nicely in the 55° seat.

5. What G-Protective technique do you normally use at high G?

   Muscle tensing and Crouching

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout; pressure too high, too low or about right etc.)?

   Not enough experience.

7. Any other comments?

   None

3 March 1975

PILOT #17

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Yes

2. Was this indoctrination of any benefit to you? If so, in what way?

   Yes, the effects of seat back angle were physically felt and I can attest to the benefits of a reclined seat.

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required, etc.)?

   20° — no grayout at 6 G, heavy straining in breathing at 6 G after 15 seconds.

   55° — very comfortable, chest pressure increased but breathing at 6 G was comparable to 3 G level in 20° position.

4. What if the G levels had been higher (e.g., 8—10 G)?

   20° — impossible

   55° — should be possible — I can forsee increased breathing problems with increased chest pressure.

5. What G-Protective technique do you normally use at high G?

   G-Suit, M—1 Straining and Muscle tensing.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout; pressure too high, too low or about right etc.)?

   Until now I had not realized that there was a change in G-suit pressure.

7. Any other comments?

3 March 1975

PILOT #18

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Yes

2. Was this indoctrination of any benefit to you? If so, in what way?

   Yes, a studied evaluation in *sustained* G. Most of my experience has been in *transient* G.

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required, etc.)?

   20° — Better than F-4 or T-38 etc. (i.e., 13°)

   55° — Far superior to anything I've flown.

4. What if the G levels had been higher (e.g., 8—10 G)?

   I feel that the reclined seat may be required for sustained G at these (8—10 G) levels.

5. What G-Protective technique do you normally use at high G?

   G-suit, M—1 Straining — most, and Muscle tensing — a little.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout; pressure too high, too low or about right etc.)?

   Reduced pressure was not noticeable even though I knew about it in advance.

7. Any other comments?

   HAC is an outstanding program for future high performance fighters.
   Thanks and good luck.

3 March 1975 **PILOT #19**

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Yes, I was briefed on the system at Edwards AFB, approximately 2 months ago; but I had no actual G-simulation until this run.

2. Was this indoctrination of any benefit to you? If so, in what way?

   Yes — first experience of *side* stick control. First experience of tilt-back seat under G-loading.

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required, etc.)?

   20° — Straining required at 6 G level. No grayout tendency as long as I strained using M—1 maneuver.

   55° — Much less straining required. Never a tendency for grayout. Easy working environment.

4. What if the G levels had been higher (e.g., 8—10 G)?

   I feel confident I could work effectively in the 8 to 10 G.

5. What G-Protective technique do you normally use at high G?

   G-suit, M—1 Straining, Muscle tensing and Crouching.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout; pressure too high, too low or about right etc.)?

   Reduced G-suit pressure was not noticeably different.

7. Any other comments?

   65° tilt back was very comfortable environment.

3 March 1975

PILOT #20

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Yes

2. Was this indoctrination of any benefit to you? If so, in what way?

   Yes. Proved that tilt works.

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required, etc.)?

   20° —

   55° — Up to 3 1/2 G/s had no discomfort whatsoever — tolerance at 6 G was greater than 20° seat.

4. What if the G levels had been higher (e.g., 8—10G)?

   Could have taken 8 G; however, G-suit was a little tight and proved uncomfortable in stomach area.

5. What G-Protective technique do you normally use at high G?

   G-Suit, M—1 Straining, Muscle tensing, and scream a lot.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout; pressure too high, too low or about right etc.)?

   My particular G-suit was fitted too tight around waist leading to some discomfort.

7. Any other comments?

3 March 1975

PILOT #21

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Not from self test — but from being told.

2. Was this indoctrination of any benefit to you? If so, in what way?

   Appreciation for the new techniques — helped form some personal ideas of like or dislike.

3. Could you compare the two seat positions (i.e., comfort, grayout; straining required, etc.)?

   20° —

   55° — Slight grayout at each immediately at onset; caused by being sneaked up on! After that the higher tilt required less action to fight off any graying tendencies, however, more pain at the higher tilt position in the lower rib cage/upper abdomen near sternum base. Some ankle pain at the low tilt position.

4. What if the G levels had been higher (e.g., 8—10 G)?

   The pain in the chest would have been fairly bad.

5. What G-Protective technique do you normally use at high G?

   G-suit, M—1 Straining, Muscle tensing and squint.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort, protection against grayout; pressure too high, too low or about right etc.)?

   I wasn't near graying out, but the chest pressure from the G-suit was very high.

7. Any other comments?

3 March 1975

PILOT #22

1. Prior to today's indoctrination runs, had you been aware of the effect of seat back angle on human tolerance to acceleration?

   Hearing only.

2. Was this indoctrination of any benefit to you? If so, in what way?

   Yes. Reclined was possible to relax all body forces and let G-suit take care of blood drainage. Upright this was not possible.

3. Could you compare the two seat positions (i.e., comfort; grayout; straining required, etc.)?

   20° — at 6 G very narrow field of vision.

   55° — no body forces required — able to look around at approximately 70° field of vision.

4. What if the G levels had been higher (e.g., 8—10G)?

   Probably more pronounced differences.

5. What G-Protective technique do you normally use at high G?

   G-suit, and Muscle tensing.

6. Could you comment on the reduced G-suit pressure in the reclined seat position (i.e., comfort; protection against grayout; pressure too high, too low or about right etc.)?

   Pressure felt the same but muscle tensing was much less.

7. Any other comments?

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