NASA Technical Memorandum 84258

A Piloted Simulator Investigation of Stability and Control, Display, and Crew-Loading Requirements for Helicopter Instrument Approach Part II — Supporting Data

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September 1982

National Aeronautics and
Space Administration

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A PILOTED-SIMULATOR INVESTIGATION OF STABILITY AND CONTROL, DISPLAY, AND CREW-LOADING REQUIREMENTS FOR HELICOPTER INSTRUMENT APPROACHES

II. SUPPORTING DATA

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APPENDIX A

PILOT RATING COMMENTS

CONFIGURATION T30

Pilot G
Runs 213-215
Ratings;* DP = 6; SPMA = 7-1/2; SPCA = 7-1/2

Dual Pilot

Again, 213, one factor in this series of pilot ratings is the learning curve. I've got one set of flight director-flight control system here that I've been dealing with, particularly in the pitch collective axis, that I'm learning a little bit about. Although, I'm probably doing better with it now than I was at the beginning of today's period. There's a lot of pilot workload there, a lot of pilot concentration, instrument scan, and a couple of times, I tended to start to overcontrol it. I really had to concentrate to prevent a divergence there in glide slope and airspeed as they talked to each other.

Certainly, I was able to adequately perform the task. The airspeed tolerances and the glide-slope tracking weren't that good, but it was a situation where maybe you would have a failure somewhere and if you would want to get down through the overcast you could do it, even execute the missed approach, as long as you are a dual pilot.

I could just guess a little bit what would happen if I had to turn my head away and change a frequency. I am sure the thing would really go on its belly here, belly-up.

Okay, pilot rating-wise, I would have to rate this — I give it a six to a six and a half, and tracking and intercept — first of all, altitude control on the level was okay, as long as you kept everything where it was at I.C. As soon as you start to maneuver a little bit, then it starts to get away from you, requiring a very high intensity tracking task. I definitely did detect some coupling from the collective. I had to retrim and I checked it this time and then, sure enough, there was a little bit there. It's not completely decoupled about the roll axis; however, it is fairly subtle.

The breakout and the missed approach were okay for the pilot rating I gave, representative. Pitch and roll sensitivity and predictability were okay.

Collective — I've mentioned the coupling. The yaw axis behaved itself. The displays — no flight director at all. I had to really concentrate on maintaining attitude control which is the way you fly instruments. Concentrate on that. I had to keep a good scan going of the raw data. I was able to do that, but this task of scanning was a high workload task, and I would anticipate that we'll have problems with auxiliary tasks and that's the end of my comments.

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*DP = dual pilot; SPMA = single pilot, missed approach; SPCA = single pilot, continued approach.

Single Pilot: Missed Approach

Alright, pilot comments. Saturation — that certainly was worse than a six and a half. I think the point here is that I was unable to write anything down; I had to really keep my eye on it or lose it and this broke down my communication procedure routine, obviously. I feel that's an inadequate performance. I am going to rate it a seven and a half, for obvious reasons here. No flight director to help me, and no attitude stabilization to help me. I've got the worst of two worlds, and I think it's inadequate for any consideration — even for dual, although we have rated that better.

The intercept and tracking were — everything degraded, and the highest workload, of course, during the missed approach, clearances, etc., everything went to pot there. I didn't feel I was going to crash, but it certainly was uncomfortable all around. So, rate it a seven and a half, because it is borderline on the controllability question. I think that is all of my comments.

Single Pilot: Continued Approach

On Run number 215, I heard the words "last approach." I didn't have everything set up in the cockpit here. It gave me kind of a realistic task. I was cleared for the approach and discovered I had the wrong frequency in because I wasn't getting the right response on my instruments. I dialed it in and ended up flying a very loose off-optimum approach down to minimums, but I ended up at breakout somewhere in the vicinity of the heliport, so the tracking errors that we'll see on this particular run will evidence all of that extra stuff that was in there. I also put a wrong transponder code in.

Again, that's not worth certifying at all; in fact, it's not worth subjecting a pilot to again. I am going to give that a seven and a half, again, for the same reasons, and that's the end of my comments.

CONFIGURATION T01

Pilot M
Runs 139-141
Ratings: DP = 7; SPMA = 8; SPCA = 7

Dual Pilot

I would say that on that approach the workload was almost intolerable. Let me read my chart here. At the bottom I went to full-needle deflection on the glidepath, which would have been an automatic missed approach at that point.

I think, overall, on that one, just from the workload, the coupling that I saw on all axes, I would have to say that one was a seven. Even though the collective tab was a help, the sensitivity of it caused quite large collective inputs which caused me to have to concentrate almost strictly on the attitude indicator and with a strong cross-check towards airspeed. Even in a dual-pilot situation, the coupling that we have, I think would really be maximum tolerable pilot compensation. Again, controllability was not in question. I felt I was in complete control and was able

to at least work towards the desired glidepath information and the azimuth information, but again a very intense cross-check. Overall a seven.

If the tape is still running I could say that the lack of a wing leveler was also noticeable on this one. I had thought that was a very subtle aid but it seemed to be stronger, especially with this particular control system. It was more of an aid than I realized, now that I can look at the situation I have without the wing leveler.

Single Pilot: Missed Approach

I think I have to give that one an eight in that considerable pilot compensation was required. The control of the aircraft is becoming a factor, especially in the pitch axis. Large excursions were noticed, especially during the tasks associated with the missed approach. Inbound on the MLS, I felt I was able to relatively closely track the azimuth and the glidepath information but, especially when the large changes were required, the power change at the bottom required to begin a climb and trying to maintain 60 knots, it took an extremely heavy concentration on the attitude to maintain the airspeed and to establish a climb rate out.

It really seemed as though I was more comfortable and able to control the attitude better when I was in a turn — turning about 150°, getting to the Santa Barbara radio. I felt relatively stable, the control activity in the longitudinal axis didn't seem to be as great as it was just on a straight descent changing to an ascent and the power changes associated.

I noticed, again, coupling in all axes — in the roll and the pitch. Quite a lot of pedal activity, also. Overall I felt that a couple of times when I was doing something and came back again, it was a recovery from an unusual attitude. As I say, I think I am tickling on the control — being able to control the aircraft adequately with the information I am getting. I would, overall, give that an eight.

Single Pilot: Continued Approach

Overall, I think, again, I would have to give that one a seven. Adequate performance was not attainable. I had some extremely large deviations on attitude, especially during the additional tasks in the cockpit. I felt, this time, I was able to catch them a little sooner during conducting of the additional tasks and, therefore, I didn't feel that I was approaching the controllability problem. Although, the extensive cross-check required in order to prevent a control problem was there. I feel the maximum tolerable workload, pilot workload.

I really seemed to have more of a problem in the pitch axis than any other. Again, the collective tab did help me, but I felt as if I was almost continually in an unstable situation, that unless I was on top of the situation 100 percent of the time, I was going to get these large excursions. Not having the missed-approach task and the workload associated with it, I think kept this one from being any worse. I think I would give it a seven.

CONFIGURATION T02

Pilot M
Runs 172-174
Ratings: DP = 5; SPMA = 7; SPCA = 6

Dual Pilot

Overall I think I would give this one a five. It required considerable pilot compensation. Mainly because of the pilot workload, although there were no large excursions. I was able to relatively precisely maintain the azimuth and the glidepath, although it did require a pretty high level of concentration and almost constant small corrections of the cyclic. It just appeared to me that pilot workload was considerable so, therefore, I would give it a five.

Single Pilot: Missed Approach

I think I would give this one a seven, possibly a hair more than a seven, but let's call it a good solid seven.

Adequate performance was not attainable. I think, again, the pilot workload — again, the intensity of the pilot workload in concentration needed on cross-check is bumped against doing the additional tasks within the cockpit. The performance really went down. I think once everything was done and I was stabilized on the glidepath and the localizer, the workload was about a five or a six workload. But when you throw the other tasks in — there was one time when I had mis-tuned the transponder about the time I went down and looked at the transponder and looked back at my knee board and back to the transponder, I had about a 30° bank going and the deviation of the command bar is somewhat disconcerting when you look and you see almost a full-scale deflection of the command bar, but when you cross-check that against the raw-data localizer, you find that you are not that far off and I was able to relatively easy bring it back. Overall I would say that controllability is not in question. I do feel that I had complete control with it except for that one deviation, but I did catch that, so — overall, a seven.

Single Pilot: Continued Approach

Again for the task, I would give it a six. Extensive pilot compensation. Certainly from the pilot workload in the cockpit; there is almost constant control activity on all the axes, the longitudinal and the lateral and collective became very annoying and I was never really able to settle down, especially the glidepath and the vertical speed. Constant turns, constant adjustment of attitude, which again, required almost a complete attention. Although I didn't have any large excursions, I think my learning curve in the cockpit, the additional tasks within the cockpit have helped. Again, without the missed approach, I would call it an extensive pilot compensation and give it a six.

Pilot G
Runs 210-212
Ratings: DP = 6; SPMA = 7; SPCA = 6

Dual Pilot

On 210, as these evaluations proceed through the matrix, I'm appreciating more and more what a flight director can do for you, although we've lost the lateral, the low-attitude loop. The vertical steering bar, that is, the roll steering bar, helped me considerably in tracking that azimuth, coping with the sheers, and so forth.

I did notice, I felt, maybe there was some roll due to collective in there with that loop out of there. I guess a free run would have shown that. I didn't bother to put in any inputs and to test it out, but I did do some lateral trimming after that transition onto the glide slope. I felt, maybe, there might have been some lateral — some rolling moment, due to collective.

Okay, I worked pretty hard for airspeed control and glide-slope control combination there, and it worked out pretty good with full attention on the instrument scan. However, it is a high workload.

Pilot rating-wise, let's see, I am going to rate it a six, let's make it a five and a half, on the pilot rating. I changed my mind, again. Back to a six.

The intercept and the tracking went along okay. I had to be very conscious not to overcorrect the airspeed errors with too much pitch attitude and, thus, throw myself off my glide slope, as in the previous configuration. I'm getting more and more practice in coping with that. I did have more trouble laterally but, the flight director, again, came to the rescue. I would say there was a little bit more workload, though, compared to the last configuration. Thus going from a four and a half for dual down to a six here.

The same comments on the intercept and tracking — a deficiency in the flight control system; that is, lack of a roll attitude loop as made up for by the sophistication and the display; that is, a roll flight director. So, that looked good there.

The pitch and roll responses — no further comment on those. Sensitivity and predictability are okay, no problem. Collective — I did mention, I felt some roll due to collective in the conventional way. That is, down collective, roll left — up collective, roll right. The yaw axis seemed to be behaving itself. The breakout force on the pedals, of course, has been low on these, and I had to be careful I didn't push a pedal, inadvertently, here, and kick in some sideslip. I've done that on a couple of isolated occasions. I think I did on this approach a little bit, small sideslips. Displays — I think I've talked about the flight director already, particularly, the roll flight director.

Collective flight director — Same as for the last configuration. It is very helpful for staying on the glide slope, but you must remember not to make any large pitch-attitude changes for airspeed control.

Auxiliary tasks don't apply, and I am standing by here for a dual-pilot, that is, single-pilot run.

Single Pilot: Missed Approach

In run 212, I think loss of the roll axis showed up this time. I was busy in the cockpit here. I didn't even have a chance to write those clearances down and, yet, I lost roll-attitude precision control here. I didn't crash but, the airplane started gaining speed. I went up to 100 knots and you got some inadvertent roll attitudes established and, I think that just crossed the six and a half borderline. I am going to rate that a seven. I feel that that is an inadequate performance when a single pilot cannot perform a missed approach with at least some attitude precision. So rate that a seven; however, I didn't feel that — let's call it a seven and a half. Controllability was in question there a couple of times — that part went through my mind.

The problem here, although we have a flight director to compensate for poor handling qualities, is a poor flight control system; if you take your eyes off of it it is not available and, thus, you can upset the aircraft either by inadvertent stick inputs or by just letting go of the stick, which I didn't do in this case. I think those are all the comments, because I've covered all the rest of them in the previous discussions. That is it for this series.

Single Pilot: Continued Approach

Run 211 is without having to execute the missed approach with the associated increase in workload due to the auxiliary tasks. The only thing I saw was the thing I have been complaining about on this particular configuration: poor airspeed and glide-slope control. It starts out by an airspeed error. I do have a flight director for collective. As long as I am on airspeed, that's working near zero and keeping a fine track on that — once the airspeed drifts off, again I make a correction in pitch, which is usually too much and it gets the glide slope off, and so on. It is just a high workload situation and, again, it could be dangerous down near minimums. I feel it is still a six and a half or better, but I will rate it a six to a six and a half again.

I didn't really feel the loss of the lateral — excuse me, the roll-attitude stability term. I think that's what I lost. Again, the roll flight director compensated for that. Okay, comments, the only ones there would be in addition to the ones I've already given for this configuration would be, with respect to auxiliary tasks, this one — the auxiliary task was without the missed approach, so I was able to give that a six to a six and a half rather than crossing the borderline. That's the end of my comments.

Pilot K
Runs 261-263
Ratings: DP = 4; SPMA = 5-1/2; SPCA = 5-1/2

Dual Pilot

Okay, based on — basically, that one, I thought was fairly well-behaved laterally and directionally, but it was the pitch axis that took a lot of the attention. No doubt, I think, the flight director is helping me with this one, so I am going to base my comments and rating definitely with the flight director, because, really, the cues

I had — the collective cue and the azimuth cue put glide slope, localizer information, on the same part of my cross-check as the attitude — aircraft attitude indicator with pitch and roll. So, it did come in quite handy.

Speed control was a problem, not only because of — that is, that only because of aircraft pitch, pitch attitude control. This aircraft was acceptable for a two-pilot. I would like to say that it is unsatisfactory, though. It took moderate pilot compensation. I will have to give it a four.

Single Pilot: Missed Approach

Certainly not unlike the previous one. It was a beast in pitch. Fairly poor presentation of my pitch-attitude requriements. All I had was an airspeed indicator. So the speed control was — it varied in the final stages of the approach. I got speed control fairly close, but I think it was quite relative to the turbulence level I was getting. I was expecting bad things on the missed approach and they didn't develop.

It appeared as though speed tracking on the missed approach was pretty good. I was fairly comfortable, but in the later stages on final it was exactly the same as the previous model. A high workload, it was acceptable single-pilot but, certainly unsatisfactory — moderately objectionable deficiencies — considerable pilot compensation, and I'll give it a five and a half. I think that's what the previous one got.

Single Pilot: Continued Approach

That one, I think, did not have a wing leveler; in fact, the interesting thing about this last run was that I had more problems with it, the control task, when I had no auxiliary tasks to do. Even as I was concentrating on the control task, my workload was higher than the two-pilot task. The possible reason for this is, with the auxiliary tasks thrown in, my excursions were so great while I was doing the auxiliary tasks that just correcting back to the correct flight state took so much more workload, but I actually had a harder time with the control task. The control task, again, it was mainly pitch-speed control that was my main gripe on this one.

I would have to say that it requires considerable pilot workload — but, it is acceptable, however, but definitely nonsatisfactory. It needs improvement. I think I would have to say that there are moderately objectionable deficiencies and considerable pilot compensation. I will have to rate that one a five. Make that a five and a half.

CONFIGURATION TO3

Pilot M
Runs 13, 14
Ratings: DP = SPMA = 4

Dual Pilot

Again I have the full flight director. No difficulties in acquiring the localizer, the azimuth. It appears as though I had a little further to go on this particular approach than I did the last time, but still it was very comfortable. I felt I had good control as far as the roll axis — the pitch axis, again it gave me a little workout, both on — during the acquisition, the deceleration to 60 knots, and maintaining a precise airspeed down the glidepath. Again I felt I was about a half cycle out-of-phase with the thing and only by cross-checking airspeed can I maintain a constant airspeed coming down.

No problem with the displays — the lack of any other tests in the cockpit, again, helped. No special problems that I noted. Overall, I think that I would give this one a three in that it had minimal pilot compensation. It did take a pretty healthy concentration on the flight director, especially on the pitch axis in order to maintain the desired airspeed. So, I will give this one a three.

Single Pilot: Missed Approach

Again no great difficulty in acquiring the azimuth. Initially the airspeed was no problem. I was able to fly up to the outer marker with very few control inputs. The tasks that I had to accomplish were not too bad at that point.

During the descent, I do believe that, again, that pitch seemed to vary quite a bit, the pitch command bar; therefore, as a result I had a varying airspeed with the associated tasks. Again very hard to cross-check raw data.

The beginning of the missed approach, I used the go-around mode and I really had a problem, both with pitch and with the collective axes. There was a coupling there, an apparent coupling that occurred and I was never able really to stabilize both of them at the neutral position. When the clearance was ready to come, that's when I said, "stand by," because I was trying (1) to control the aircraft to try to get the bars relatively centered, and the pitch, the collective tab — I finally managed to, and then as I was copying the clearance; naturally, as I switched hands back to the cyclic, I hit the reset. So, if there is any major problem on this pilot-to-machine interface, I would say it is me and the trigger switch.

Overall though, as far as the workload, and I think that would be the biggest downgrade on the thing — the fixation necessary on the pitch command bar and having to essentially mentally integrate it myself, the rate of change of that bar in cross-checking airspeed, I think it would require moderate pilot compensation and so, it would be a four.

Pilot G
Runs 67-69
Ratings: DP = 5; SPMA = 8; SPCA = 7

Dual Pilot

Okay, we've lost a roll-attitude loop compared to the previous configuration I just looked at it, and I really don't see much in the way of degraded handling, nor do I see any significant increase in pilot workload. I feel the lateral flight director apparently is giving me information I need to cope with lateral guidance here despite the lack of a roll-attitude loop. However, the overall workload for the whole task, even with dual pilot here, is fairly high and requires a lot of attention. I was able to keep pretty good tabs on raw data so, I wasn't so intense that I had to lock on to the flight director only and then hope for the best — that type of thing is really bad.

I will rate this one a five also — rate it a five for dual pilot, and let's see — looking back here to see if there's anything I've missed on the specific comments.

The intercept — the azimuth intercept was pretty straightforward despite no lateral attitude loop; that is, no roll-attitude loop. Tracking intercept, and so on, was a moderately high pilot workload, but I was able to do it. The flight director was doing a good job to help me cope with the flight control system. The missed approach, again, was satisfactory, high workload and some wandering in pitch. I didn't like that; that's uncomfortable.

It also makes you a little uneasy to see this — the overcontrol, it's easy to get into. You really have to lock on to the pitch flight director there to keep that pitch attitude squared away. There is some tendency to chase it back and forth. That, again, is why it is rated down from a three and a half.

Okay, pitch and roll sensitivity and predictability — well, sensitivity was okay. The combination of sensitivity and damping was good. You get on the gages here, and there is a tendency to not be quite as precise with pitch attitude. That's where you need a pitch attitude loop in there, which of course, we don't have. It was predictable in that I knew that I had a rate system and that I would be chasing pitch attitude around. It's predictable from that point of view. I knew I was going to have problems.

Collective — no problem there. There is some coupling. You get pitch errors that go in to collective command errors, and so forth, but not too much on the dual pilot run I just made.

The yaw axis behaved itself. As I mentioned, the turn coordination was good on the airplane. I didn't seem to have any sideslip tendencies here, even though I got a little slow. That looks good, too.

The flight director was good — doing a good job. The sensitivity and responses were fine. I had a chance to scan the raw data. That's the end of my comments.

Single Pilot: Missed Approach

[Initial comments missing.] I also started to lose the attitude control in roll as well as in pitch and got into a fairly large, and I would consider dangerous, attitude departure. That's bad. I have to rate this way down for single pilot. I don't think it is a function, necessarily, of the missed approach, although, climbing, that is, the high power setting may upset the dynamics of the airplane a little bit more than cruise is already set for the approach power. Certainly it happened during the high workload period in the missed approach and getting the clearance.

I will rate that a good old solid eight — a pilot rating of eight for that specific incident or worse-case situation that I just described. Specifically, I think I've covered most of the handling-quality traits here that I would repeat here.

The intercept and tracking went along as in the dual-pilot case; however, the missed approach was the bad one where I almost lost control, and that's because of the auxiliary duties in the cockpit here, auxiliary tasks.

Pitch and roll sensitivity were okay; however, without the attitude loops it was easy for me to inadvertently put in some pitch and roll heights that upset the aircraft — inadvertent pitch and roll due to moving the stick while my eyes were looking elsewhere in the cockpit changing frequencies.

Collective — I have no particular comment on there or on the yaw axis, but cyclic — pitch and roll — was where I seemed to lose it due to lack of attitude there.

Displays helped — I think if I had a raw data and got into that situation, I may have gone into the water. I may have possibly really lost control and crashed; that's why I am keeping the rating at an eight, considerable pilot compensation required for control. That was really the case there for a short period of "terror" there.

During that period, I was not looking at the raw data. I could see that I was getting low, the altimeter was unwinding, etc. So, raw data was not scanned too well because I was trying to regain control through the use of the attitude indicator and the flight director needles there. That's about it. I think I've covered the auxiliary tasks and have no other specific comments. That's the end of my comments.

Single Pilot: Continued Approach

This is run number 69. Here's a case — we have a very sensitive — we have a flight control system that's very sensitive to pilot workload, whether it be dual-pilot or single-pilot. It is very sensitive to the single-pilot workload, and I guess we can also say that the learning curve might be a small factor. If I am able to keep my eyes on the instrument scan, this combination seems to be acceptable even though it is single-pilot. If I have to look away for very long, then I am going to lose it sometime; that is, lose trajectory or attitude control sometime in the approach. It can get away very, very quickly once it does. Here's a case where I didn't have to execute the missed approach and copy the clearance and do a higher auxiliary task workload, which the missed approach is associated with. I got through the approach okay without scaring myself. However, I still feel it's not satisfactory. I am just trying to decide whether — I feel the major deficiencies and the sensitivity — the two distractions are so great that I am going to rate it below a six and a half, although you could get — I made a satisfactory approach, but I feel

that it is so close to being unstable that I don't want to rate it better than a six and a half — I am going to give it a seven. Can you follow all of that?

(Response: We have followed it and your comments are recorded as a seven on the rating.)

I don't think there's a need to go through the specific comments list. I think I have given you the gist of it. It's just a flight-control system that can really get away from you — if it does, the flight director will help you to retain control depending on how far you have deviated off and, again, it is very sensitive to auxiliary workload tasks. That's the end of my comments.

Pilot K
Runs 147-149
Ratings: DP = 5-1/2; SPMA = 7; SPCA = 6

Dual Pilot

That one wasn't nearly as good and what I missed on that one was the attitude-hold in pitch. My task in pitch was considerably greater and this was extremely noticeable about half way down the glide slope. When I had an excursion in glide slope, I ended up pretty close to two dots high, which meant that this was a fairly gross abuse case to get back on to it. I came back on all right, but I just didn't like the excursion. It wasn't all that apparent for just sitting in the cockpit — the cockpit motion two dots above.

A fairly high workload on the missed approach, too. I would have to say that it requires considerable pilot compensation. The workload was fairly high. I don't think it was maximum compensation — it was extensive so, I will have to give it a five and a half.

Single Pilot: Missed Approach

I specifically looked at this one with the single-pilot task and what happens when I just let go of it, get away from it, reach over and dial frequencies. The auxiliary tasks have an extremely powerful influence on this one; mainly, because you just cannot let it go for a very long period of time. Although it has rate damping, it almost appears as though it tends to depart much too quickly to be of any use at all on the single pilot. The single pilot IFR environment, that is. Really, the pitch and roll axes are just about as much at fault; however, the pitch axis is much more noticeable.

Speed excursions on the missed approach when you reach and dial, you tend to just leave the attitude alone for awhile, ignore it, and go on and dial some frequencies. Speed excursions are extremely gross.

On this one, I would have to say that it requires extensive pilot compensation — probably even worse — it is bordering on the unsatisfactory. Well, including the auxiliary tasks, it requires maximum pilot compensation. In fact, when you do auxiliary tasks, you pretty well have to monitor the airplane yourself. You've got to do two tasks at one time. I would have to give this one a number seven.

Researcher: We copy a seven and we read that as saying you thought the performance was still barely adequate, but you were working too hard. Did I understand that correctly?

Pilot: That's correct. It is maximum pilot compensation. The performance may be adequate. It is getting pretty gross. The . . . in glide slope, I thought was quite gross. Excursions down to 20 knots below nominal — 20 to 25 knots below nominal on the missed approach, I thought, and speed was very gross. It is bordering on pretty poor performance. However, I'll say that it is probably adequate.

Controllability was probably adequate. Controllability wasn't quite in question just yet because the pilot could always forget about the auxiliary tasks, neglect the auxiliary tasks, and concentrate on the controllability and get it under control.

Single Pilot: Continued Approach

On that one, I concentrated mainly on not letting the airplane go — not ignoring it. Paying almost full attention to the control task. While I was doing auxiliary tasks and tuning in radios. I made sure I still monitored the flight director. It worked out better, but I don't think that is an acceptable thing to expect in single-pilot IFR operations, at all.

I would have to say that probably on this run I will give it a little bit better rating. A noncommittal rating, like a six and a half, which leaves it borderline between unacceptable and acceptable.

Researcher: Cockpit — we've never had a borderline reading. Can you make a decision between unacceptable and acceptable?

Pilot: I guess I will call that one a six, which is acceptable, but barely. It was simply because of my technique of concentrating on the control task and not letting the auxiliary task detract from it at all.

Pilot M
Runs 281, 282
Ratings: DP = 5; SPMA = 6-1/2

Dual Pilot

Overall I would give this system a five, although the precision I flew it with, I was satisfied with, I was able to maintain the glidepath and the azimuth. However, I did feel that I was chasing the command bars considerably — the pilot activity, the control activity seemed quite high. The intensity of the cross-check, staring at the command bars — a very intense cross-check between the three axes on the command indications, and I would say that any time — in fact, I did not even get a chance to go to other instruments for a secondary cross-check. Anytime I would break that command bar cross-check, I would sense that I would be getting a deviation.

Overall I would say considerable pilot compensation and it was a five.

Single Pilot: Missed Approach

I think with this one it is a six and a half; in that, during the approach, any additional task within the cockpit would cause some large deviations. You had to do the task — break down the task and any small subtasks in order to get back to your cross-check of the command bars and try to keep the rotor pointed somewhere generally at the sky. I got some fairly large deviations, especially, when it came to the missed approach. I had quite a bit to do on both sides of the cockpit and really noticed every small attitude change when it affected vertical speed and, therefore, the command bar. So the control activity was tremendous. I would say it required extensive — well, on the approach, extensive pilot compensation and on the missed approach — the maximum tolerable pilot compensation. I think some of the excursions that I had on the missed approach were a lot larger than those that I had on the approach itself. Overall a six and a half.

CONFIGURATION T10

Pilot M
Runs 94-96
Ratings: DP = 4; SPMA = 7; SPCA = 6

Dual Pilot

Okay, dual-pilot approach without the flight director — I would say it required moderate pilot compensation just from the cross-check required. I was able to intercept with no great effort. Aircraft response — again, no significant comments on that. There did seem to be a little bit of a collective — yaw coupling that occasionally threw off my desired heading, but I was able to easily concentrate. With the intensity of the cross-check, I made the corrections. The raw data scan — I was able from the sensitivity of the raw data, I had time to go to the other instruments; the vertical speed, airspeed; in fact, on that one, I was even using a variation of changing power in order to change my rate of descent. There was no real problem with that.

Overall I would say moderate pilot compensation just because of the scan required of the raw data — no associated task to perform, no clearances; so, no great problem.

Researcher: Say again the pilot rating.

Pilot: A four.

Single Pilot: Missed Approach

I think overall I would give that a seven. I wasn't really happy with the performance on that. I had some fairly large deviations, almost an unusual attitude recovery there, especially in the pitch axis. I got into almost a cycle with the pitch axis and the attitude indicator and — controllability is not really in question. Once I would come back to the attitude indicator and really get a tight cross-check going again, that was the key in adequate performance on this one.

With the additional tasks in the cockpit, I found that any minor deviation or breaking of that tight cross-check caused a rather large attitude change and requirement to recover from — as I say, almost the feeling of recovering from an unusual attitude. That's the basic key. I think that the maximum tolerable pilot compensation was required, but again controllability wasn't in question due to deficiency. Overall, a seven.

Researcher: I expect that you're forgetting that call tower was the good indicator of that, also.

Pilot: That was a factor. I had come back and I changed to the frequency — to the tower frequency and then I got awful busy and really had to concentrate on the cross-check again. That was an indication, that's true.

Single Pilot: Continued Approach

Overall, I think, since I didn't have the missed approach task on that one, I would give it a six, in that extensive pilot compensation was required but I was able to still maintain my level of performance. I feel that I did intercept — I felt I was a little tighter on the azimuth and the glidepath on this one — this pitch, than I was before. Although at one point, I did get almost two dots deviation, which would have required a missed approach at that point, but I was able again to expand the cross-check just a bit and get to the vertical speed, make some inputs, and salvage the approach. Overall, though, because of the cross-check and, again, I seem to have more problem in the pitch axis but, on this particular approach, not quite as much as I did before. Overall I would give this one a six.

Pilot K
Runs 186-188
Ratings: DP = 4; SPMA = 4-1/2; SPCA = 4-1/2

Dual Pilot

On that one there was a lack of attitude retention. Inputs in the pitch mode certainly were a factor, although I was hands-on for the whole task, the control task. There's no doubt that the attitude retention is rather a good thing, even for the two pilot task.

It wasn't overly bad, though, the aircraft appeared fairly well damped both laterally and longitudinally — it felt really good; the wings leveler and the attitude retention in roll seemed very comfortable.

I could have either used a single pilot — I had better forget about single pilot. In any event, I think I had a moderate workload on this thing. For a two-pilot task, I would have to give this a four.

Single Pilot: Missed Approach

That wasn't too bad. Even with the missed approach . . . base this on missed approach, I will also give that a four and a half. Much the same comments. I had moderate compensation, I didn't think the workload on the missed approach was all that much heavier.

Single Pilot: Continued Approach

I thought I was going to have to do a missed approach on this one. Okay, going I.C. That one, as in the two-pilot case, was not a mad model to fly. I could use a bit more pitch damping, though, or possibly pitch-attitude retention. However, not all was bad. A few excursions in glide slope there, fairly gross excursions. They were not due to me doing auxiliary task, but just inattention on my part. I am going to disregard them in the rating, because I certainly could have done without those excursions.

I still had a fair bit of pilot compensation . . . workload and I will have to give that one a four and a half for the single-pilot task.

CONFIGURATION T11

Pilot M
Runs 136-138
Ratings: DP = 5; SPMA = 6; SPCA = 6

Dual Pilot

I think I will give this one a five in that it required considerable pilot compensation. I had collective to pitch attitude coupling and, therefore, airspeed — I had some relatively large attitude excursions and I had some large deviations in airspeed — as much as 10 or 12 knots, both fast and slow. It required — the control activity required me to maintain an altitude — correction, maintain an attitude.

It was noticeably higher — very high. The localizer didn't seem to be that much of a problem. I was able to use it, the wing leveler to an advantage during the approach. The collective command tab did help in that I was able to see on what instrument the ADI required inputs for collective, but as I would make inputs, I would get the large attitude deviations or attitude excursions.

Overall, the concentration was considerable. The cross-check required was considerable so, overall, a pilot rating of five.

Single Pilot: Missed Approach

I think I will have to give this one a six; although, I didn't complete the entire missed approach procedure, I felt I had a pretty good handle on it. The concentration, the pilot effort, the attention maintaining the glidepath and the localizer — I would call it extensive. Again the coupling that caused the large — several large pitch excursions, I would say as much as three bar widths of the attitude indicator. The airspeed varied between 48 knots and, at one point, inadvertently, I was up to about 75 knots. Although those excursions — the maintenance of the glidepath and the azimuth, I would say were adequate — I never felt that control was in question but, it would require extensive compensation. I feel that I was pretty close on the glidepath and the localizer. I never reached the missed-approach criterion. I think the rating may have dropped slightly had I completed all of the task in the cockpit associated with the missed approach. I just started tuning the White Lake VOR and I got the heavy pedal vibration. I really felt that at that point, that

distracted me a little bit and I really had a large pitch-attitude excursion from the power change — adjusting that on the missed approach. That possibly might have lowered the rating to a seven, saying that adequate performance was not attainable, but for the tasks that I did accomplish before we had the problem with the loaders, I would say it was a six.

I think the only thing to do with that stupid rudder is to try another approach and see whether it goes again, okay?

Single Pilot: Continued Approach

On that one, I would say that it required extensive pilot compensation. Again, the concentration; specifically, in the pitch axis, the pitch coupling that I received due to a pitched-up collective to pitch coupling. I was able to open up the cross-check a little bit on that one and cross-check my vertical speed and the glidepath a little bit more than I had in the previous ones. Therefore, I was able to slightly anticipate what the collective command tab was going to do for me but, even so, making any large changes — specifically, whenever I encountered the glidepath and had to make a large collective reduction, it took me a bit to get back on the desired airspeed. Excessive large pitch excursions — large airspeed excursions. Overall, the intensity of cross-check, I think would cause that to be a six.

CONFIGURATION T12

Pilot M
Runs 169-171
Ratings: DP = 5-1/2; SPMA = 7; SPCA = 6

Dual Pilot

I am going between a five and a six on that one — let's call it a five and a half and split the difference. The lateral and the azimuth command bar both gave me quite a bit of help as far as maintaining my localized course; however, again, I noticed a tremendous amount of coupling that required an extensive amount of cross-check between airspeed, the collective command bar, and the attitude of the aircraft — looking at the attitude indicator through the command bar. So, essentially, that was splitting my concentration at that point. Although I was able to maintain the glidepath and the localizer, it did require, as I said, extensive concentration, mainly because of any small collective change would give me a tremendous pitch attitude change and I would have to, about that time, recover. I almost felt that several times, both laterally and longitudinally, I was just about in phase with the deviation. Control activity in the pilot workload, I think, will show up. I felt like I was constantly moving the stick — any change I would make would affect the other axes. I think, overall, I would say that this was between a considerable and an extensive pilot effort required and the cross-check again — I will give that one a five and a half.

Single Pilot: Missed Approach

Overall, I think I would — again, I'm torn between two. The performance on the missed approach, I don't think was satisfactory. Therefore, I think the performance on the approach — was. I think I will split the difference again and give this a six and a half.

Specifically in the pitch axis, again, I did find that the sensitivity of the lateral command bar, and the azimuth command bar — I really got in phase with that as far as control activity during the missed approach. Throughout the approach the pitch axis required extensive concentration, real extensive cross-check between the airspeed indicator and the attitude indicator. Any change in either airspeed or the collective or attitude would cause everything else to change. There seemed to be a very fine balance in an interrelationship between the three. Again, that's with the coupling that we had.

During the missed approach and the initial climb-out, I think I have now learned how to use the go-around mode properly as far as the initial climb-out straight ahead, and then tuning the VOR to Santa Barbara and using it, changing the center to a right in order to make my turn and still maintain a 00 . . . per minute; but, any additional tasks were in the cockpit. Again, airspeed really — I had some fairly large excursions on the airspeed; in fact, I was up to 80 or 82 knots at one time and, of course, my target was 60 knots for the climb-out.

Overall, I would say that approaching the approach was satisfactory as far as I was concerned, and that was the initial portion. The missed approach with the additional tasks in the cockpit, pilot workload, and concentration required — I was not — so, therefore, I will split the difference and give it a six and a half.

Researcher: Suppose that we forced you to call it one or the other, what would you call it?

Pilot: Probably down to a seven, but you won't do that, will you?

Single Pilot: Continued Approach

Overall I would have to give that one a six, a solid six. It required extensive pilot compensation and, again, many of the same comments of the last approach apply here. I think the thing that really caused the extensive workload on this one was never being able to peg a glidepath down. There was a constant requirement for changes in collective and, therefore, many small changes and, therefore, many small pitch-attitude changes that with the particular sensitivities that we have, resulted in some fairly large airspeed excursions.

At one point, about halfway down, I did have everything relatively pegged, but it was only lasting for a fairly short period of time; therefore, it took an extensive concentration on the instruments in order to — and as I say, a constant small inputs on the collective in order to maintain the glidepath.

No real problem with azimuth. The azimuth command bar does definitely help, with the total overall workload that we have with this system, it would be a six.

Pilot G
Runs 286, 287
Ratings: DP = 4; SPMA = 7

Dual Pilot

Okay, on 286, for the first approach in the morning, it is not too bad. The only thing that I saw was what I had anticipated, some speed control; however, I didn't notice much in the way of trajectory coupling of speed-control errors into the glide-slope axis. I guess the flight director was helping me there; but, I really didn't notice much in the way of disturbances in glide slope when I made some minor pitch changes there. That felt pretty good, which surprised me a little.

Let me get a pilot rating, first. This is one that I — assuming that certification as we've defined it kind of lies on a five. With that in mind, I am going to rate this one — I want to rate it a three and a half, but I am going to rate it a three and a half to a four, although the performance, I thought was quite good. The only reason I am rating it down is that there was a fairly moderate pilot workload — pilot compensation required to hold airspeed. When making a power change, there was definitely an airspeed change — it occurs because of the coupling, the lack of input decoupling — collective into pitch. I pulled in power for the go-around and the airspeed started going up, excuse me, started going down. The nose went up a little bit and, luckily, the sideslip characteristics on this particular configuration are such that it doesn't seem to want to sideslip off to the right when you let it go below 60, so — the only thing I saw there in the disturbance in the go-around was airspeed going down. I finally got that back.

Intercept and tracking were — I thought good. The breakout and missed approach were okay except for airspeed drop when power was applied for the go-around. The pitch and roll sensitivity and predictability were okay. I anticipated trouble with airspeed control with power inputs and that's what I saw. However, holding airspeed at 60 knots was almost easier than with an attitude system, which doesn't seem right. I don't know how to account for that, but with the collective and roll flight-directors to help me on those axes, I could devote more time to pitch-attitude tracking and airspeed control and, apparently, it worked out fine.

I am rating it down from a three and a half because of the potential for airspeed drift when applying power. Collective predictability and coupling, I've talked about. There is definitely input coupling, which is causing the problem with the speed. It doesn't seem to be a problem in roll or yaw, but in speed control.

Now, the flight director, I've talked about that, also. The roll and collective flight directors do a good job on their respective axes, giving the pilot more time to devote to the missing flight director and coping with the lack of attitude stability — correction, attitude loop in pitch. I was able to use the raw data, raw data scanning was never a problem. With respect to that I would, also, anticipate problems in copying clearances, particularly in the pitch axis.

Auxiliary tasks don't apply here and that's the end of my comments.

Single Pilot: Missed Approach

This is run number 287, which was a single-pilot with a missed approach and clearance. What we anticipated on this configuration certainly did happen. I had an airspeed control problem during high workload of the clearance — copying and read-back process.

I will have to mark this down — the whole procedure — the tracking, I thought was quite good — surprisingly good. I don't understand it — that I was able to hold those needles quite well, until I had to look away and take my hands off the controls, or at least switch hands here. As anticipated, the pitch control just went to pot. So I have to base my pilot ratings on that particular part of the scenario here. For single-pilot, that is an inadequate performance. I have to bring it all the way down to a seven for single-pilot.

Here we have a situation where, dual-pilot, as long as you're with your hands on the controls and you are scanning the whole time, you've got a relatively good airplane; but, using my single-pilot criterion, it is inadequate. I am going to give it a six and a half to a seven.

Briefly, the intercept and tracking — as long, I repeat myself, as long as my eyes were on the gages and my hands on the controls, everything went fine. The workload was moderate as discussed in the dual-pilot case. Even the breakout and missed approach were fine as long as I could devote my full attention to them. Then, during the clearance, I lost it in pitch, which lost it in airspeed — that's kind of the sequence of events, to repeat myself.

Attitude — aircraft response, same comments. Displays — same comments. Again, the roll flight director and the collective flight director really are great to reduce errors in those axes and then give my full attention — most of my attention to pitch tracking, as I said before. When you look away, of course, none of those factors apply.

Auxiliary tasks, of course, is the problem here. It is my reason for rating it and, again, I want to say that here's a good example of a pretty good or a certifiable combination in dual-pilot, but certainly, I feel, not certifiable — single-pilot. That's the end of my comments.

Pilot K
Runs 295, 296
Ratings: DP = 4; SPMA = 5

Dual Pilot

With that one, I recognize the configuration as dual. The biggest task there was pitch-attitude control. The pitch-attitude control felt almost as though it lacked damping or pitch-attitude stability. The pitch attitude and speed coupling seemed fine, but it was just the pitch-attitude control, I think, itself that made speed control pretty difficult and fairly sloppy.

For a two-pilot operation, it is certainly acceptable. It is acceptable; however, I don't feel that it is satisfactory without improvement. I would have to call it unsatisfactory. However, the task was performed and, except during a few large

excursions in speed, that was probably about the only time it required considerable pilot compensation.

I would have to say that it, generally, required moderate pilot compensation. I will give it a four for the two-pilot task, a four.

Single Pilot: Missed Approach

On that one — much like the two-pilot task excepting for auxiliary tasks. I had a little bit of trouble — completely letting off my control and the instrument cross-checks, so that I could do auxiliary tasks. I had to glance back to the instruments every so often while I was dialing frequencies, and so on. Again, for a single-pilot IFR, this one will be acceptable; however, it is unsatisfactory.

There are deficiencies that should be improved and that is mainly the same criticisms I had with the two-pilot task and pitch-attitude control — speed control was the main problem. I would say, probably, considerable pilot compensation as indicated by the rather gross errors — airspeed errors, especially on missed approach. I will give that a five.

CONFIGURATION T13

Pilot M
Runs 9-11
Ratings: DP = 4; SPMA = 6; SPCA = 6

Dual Pilot

Again, full flight director on this one. No problem in intercepting and tracking as far as the lateral axis was concerned. It seemed like I had more problem maintaining airspeed. I was chasing the longitudinal axis almost continually — both passing through and coming slower than and a little faster than 60 knots. It really manifested itself on the flight director and, at one point, I was almost in a PIO situation with it, but again, recognizing the rate of change and of going to a good cross-check rather than just staring at the flight director itself, going to a good cross-check with airspeed and I was able to overcome it, but it did increase the workload. It was seemingly worse than the last configuration.

No other real problems. Again, I didn't have to go to the full most approach. Having a copilot definitely helped. Overall I think I would give that configuration a four just based on the moderate pilot compensation required and chasing the pitch axis.

Single Pilot: Missed Approach

Again, on the single-pilot configuration, on this configuration, I had a, that is, quite a bit of problem with the pitch axis, and being somewhat out of phase with the flight-director command bar, I continually, as we got out airspeed and whenever I would do anything else in the cockpit even momentarily, it would really show itself up in the pitch axis altogether. There were several times when I got down as low as

35 knots and it was almost a recovery from an unusual attitude situation. It was — it was not almost — a recovery from an unusual attitude situation.

With the associated tasks — again, cross-checking the basic log data information was very difficult and I think I might have been better off on that one without a pitch flight director, because it seemed to be leading me astray. If not leading me astray, at least being very alarming to glance away and look down and see about a half-scale deflection on the command ball.

Overall, I think I would give this a six in that it required extensive pilot compensation.

That's right, there were — I was trying to use the go-around mode and I did and especially copying clearance and making a frequency change. Again, unless I was totally intent on the flight-director system, the slightest deviation and looking and associated task in the cockpit would have caused large deviations, and there were times when it took me quite a while to tune a frequency. I would start to tune and I would have to recover from the unusual attitude and then go back and finish tuning. The same thing on copying the clearance. It took me about twice as long because of the fact that I was having to be very intent on maintaining control post.

Researcher: Did the flight director display assist in recovering from the unusual attitude after a large displacement?

Pilot: Yes, it appeared to work because I was able to rapidly interpret the information that was given to me as far as being able to turn either left, right or otherwise. So the information was very valuable on the flight-director system. Although I feel that maybe the flight director — well, no I can't say that because it was associated with breaking my cross-check and looking at the flight-director system that caused me to deviate. However the flight director, itself, was helpful in getting back.

Single Pilot: Continued Approach

The pilot flight director — the major comment that I have is about the pitch axis, again. On this one I seemed to even have, during the approach, quite large deviations that almost gave me the feeling that I was in a PIO. Other comments remain about the same. I didn't really have any problem as far as the lateral tracking task. Changing the frequencies, again, when I made one frequency change, I had to make half the change and then come back and recover and go back and make the other half. That was strictly in the pitch axis. Overall, I think I would give this one a six also, that it required extensive pilot compensation, even without the missed approach. I think that the missed-approach deviations would be just a continuation of what I saw on the first person of the approach on this one.

Pilot G
Runs 23-25
Ratings: DP = 6; SPMA = 8; SPCA = 5

Dual Pilot

I had difficulty in squaring away my pitch attitude for speed control. I was pretty much chasing the flight director speed command, particularly during the missed approach.

Specific comments here — well, before I give you those. This is a rating somewhere between a three and a half and a six and a half. You can perform the task, but it's a pretty high workload, it really is.

Let's see here — certainly the deficiencies warrant improvement, and that's the obvious one. It needs a better command of speed control. I rate it down six to a six and a half, mainly for speed control. It is kind of a motherhood thing.

Back on specific comments — intercepting and tracking was not so bad. I had to chase the pitch-command bar around a little bit, but as I've already said, transitioning to the missed approach with coupling, and so on, coming in from collective — trying to trim all of that out — that became a very high workload task.

On response of the aircraft the roll was fine; of course, the pitch response is poor for IMC. I tended to really overcontrol the pitch attitude, especially when I got into the control of the pitch bar, trying to zero that. I almost went into an oscillation there. In collective, you have this old business of having the collective command and the pitch command kind of chasing each other. What you have to do is just set a priority, leave the collective alone; that is, don't move it much and square away on the pitch. This was in the go-around.

During the azimuth tracking; of course, pitch commands — the idea there is to really square away, get the pitch attitude trimmed and don't move it, then use the glide slope — concentrate on glide-slope tracking with the collective. Of course, if you let the pitch get away then they talk to each other and it starts that oscillation going.

The roll was okay — the pitch is bad, collective I have sort of talked about. There is some coupling. You can really see it, because we do not have a pitch loop, attitude loop, and collective into pitch coupling is apparent and it is causing problems. Yaw, I didn't see anything there to comment on now.

I've talked about the displays already. The raw data scan — I was pretty busy tracking the flight director, so I was unable to scan down the raw data fewer times than I really wanted to. I really wanted to go down and look at it more, but I had to concentrate on the flight director.

Auxiliary tasks aren't applicable right now and I had no other special problems. Those are the end of my comments. It is a six to a six and a half on the pilot rating.

Single Pilot: Missed Approach

Run 24, okay. To repeat, again a problem in the missed approach in trying to get the white leg VORTAC frequency tuned in. I would take my eye off the attitude indicator and without the attitude loop the aircraft pitched up, even though I tried to get it trimmed before then. I went to a very low speed and a very, very high descent rate at high power, which I'm still not sure would be possible in an actual helicopter; but, anyway, I did lose attitude control for a short while there — I consider this to be very dangerous.

With that, I must rate the thing below a six and a half. I guess I will give it an eight, based on that incident in the missed approach, not an average — that's not an average pilot rating. It's based on having lost control when looking away performing auxiliary tasks.

Down through specific comments. I think I have covered many of those. The intercept and tracking were fine. High concentration required without the pitch attitude, but I think I tracked reasonably well, nothing that was real concerning. The missed approach was the problem and I've talked about that. When I had to look away from the attitude indicator to change radio frequencies, VOR frequency, comp frequencies, and air frequencies, the pitch attitude got away. I was unable to really get a good trim on that. Aircraft response, of course, follows — a problem in pitch, primarily. The coupling in collective added, I think, to the pitch problem. Up collective-nose-up, trim change and unable to retrim it and thus, the pitch attitude got away in the slow direction.

Yaw, no comment on that. Flight director continues to be okay. One thing I did notice and, I think I am repeating myself, without pitch attitude there's a lot of cross talk between pitch bar flight director errors and collective cue errors. One, particularly, I think that the problem is that the pitch attitude wanders and causes a change in the rate of descent or climb that feeds back into the power. You put in some power that puts a pitching moment in and back and forth, back and forth, through classical coupling there. It shows up quite readily on flight director. Maybe there's a flight director logic that can be introduced that would compensate for that and lessen that tendency to work back and forth and couple into each other. I used the go-around mode to initiate the go-around and when I went to VOR and got squared away, on tracking the VOR inbound, I switched back to manual approach.

Raw data — I didn't have much time to look at raw data, to tell you the truth, until I got to the VOR part. I've talked about the effects of auxiliary tasks and their influence on the control. No other specific comments unless you have questions. That's the end of my comments.

Single Pilot: Continued Approach

That approach, overall, was considerably easier, I guess, from two aspects. A little bit of learning, a familiarity with the approach and procedures. I think the bigger one was the lack of having to execute a missed approach and copy a clearance. It was apparent to me that this control system and flight director combination is certainly a six and a half to a three and a half system — more up in the three and a half to a four range. As long as you can concentrate on it, that you are a dual pilot and that you have maintained a close tracking with it and have kept the errors small. As long as you do all of those things and have all of that going with you, then it seems to be a satisfactory combination; that is, an acceptable combination for this

particular task. If you allow an error to build up, it takes some time to get it back, reduce it, particularly because of the coupling between pitch and power here. So, this workload was considerably easier, reduced, whichever way you want to look at it. With that, about a five; it's rated a five up from the previous run which I gave an eight for, primarily because of the — I did not have to execute the missed approach, copy a clearance, and have those high auxiliary tasks workload items to perform. It is rated down, of course, because of the lack of a pitch attitude, the thing I talked about. You must maintain close tracking to keep the errors smaller or it can get away.

Back on the other side for specific comments — the intercept and tracking were moderately difficult, as indicated by the pilot rating of five. The breakout was comfortable. The deceleration VFR conditions to hover was comfortable.

I did notice some difficulty — I had some very large sideslips while trying to hover. It seemed as if I was hovering in some fairly high turbulent crosswind of some kind there; although, I don't remember seeing that before. I may be getting tired! That all looked reasonably safe and, therefore, reflecting a pilot rating of five. No missed approach required on this one. Again, pitch attitude, the lack of pitch attitude in the pitch axis was certainly missed. I noticed, again, the collective coupling into the pitch axis, primarily.

The only yaw problem I saw was trying to hvoer. I had some large sideslips, but you could expect that when you do come to a hover, anyway. The flight director, I talked about. I had more time this time to look at raw data scan.

Auxiliary tasks were not too bad. I only had to look down one time away from my panel and that is to change the transponder code. That was where the airplane was pretty well already squared away.

Again, I think the inability to trim in pitch attitude, primarily, is the big problem here. That's the end of my comments."

Pilot K
Runs 150-152
Ratings: DP = 4-1/2; SPMA = 6; SPCA = 5-1/2

Dual Pilot

. . . wing leveler is fairly significant . . . the lateral channel, I was very confident about the lateral channel — that there won't be any excursions. If I tend to ignore it, the longitudinal channels still took a fair bit of work and, certainly, it would be nice to have an attitude-hold longitudinally, or some type of attitude stabilization.

As far as the rating is concerned, I would say that it required considerable pilot compensation on that one. I was really thinking out load. I would like to think that this required considerable pilot compensation, probably a five, but I would have to say that it is probably slightly better than that. I would hate to call it moderate compensation, but a bit more than moderate. If I can give it a half rating now, I would like to give it a four and a half.

Single Pilot: Missed Approach

On this one, basically, again I looked at it with the single-pilot task to see how long I could go away from it and come back and be comfortable. The wing leveler certainly helps, there's no doubt about it. The lateral channel certainly builds up the pilot's confidence. However, the longitudinal channel — I suppose the wing leveler gets rid of about half of the problem, but probably a bit more — the longitudinal channel is still a problem. The aircraft can certainly depart longitudinally — descend at fairly extreme angles just in the time that it takes to ignore pitch attitude and the tuning of the radio by looking at it.

I would have to say that this is, again, fairly extensive pilot compensation. One could not really ignore the horizon long enough to tune the VHF. I found myself, I just couldn't stop my cross-check and carry on doing the auxiliary tasks. I had to continue to cross-check as I was doing my auxiliary tasks. I had to continue — again, sort of a two in one thing, doing two tasks at one time; which I would say was extensive pilot compensation — not maximum tolerable, but certainly extensive. I would have to give this baby a six.

Single Pilot: Continued Approach

On this one, I tried again a technique whereby I never really got away from the control task. I tried to, even while I was doing the auxiliary task like tuning in radios, I would still maintain a good watchful eye in between digits. I would have a quick glance at my flight director performance, and it seems to do the trick, if you do it that way. Just simply, you cannot get away from the longitudinal channel long enough to do the frequency change in total and come back to it. So I would feel that it was probably pretty extensive on this one and I would like to give it a five and a half, simply because I thought that probably my — I gave it a little bit less compensation required on this one, because I never let the excursions get quite as high as on the previous trip. I didn't have a gross set of gross corrections to get back. So, I am going to give this one a five and a half.

Pilot S
Runs 197-199
Ratings: DP = 7; SPMA = 8; SPCA = 8

Dual Pilot

I'm trying not to get confused here. I will have to go with a seven on that — you're walking on a tightrope and as long as it never gets ahead of you you can fool yourself to think that you're doing all right, but that's strictly from an FAA point of view. I think we'd look at that as an emergency mode fouling some sort of a double failure.

Single Pilot: Missed Approach

That's an eight, and eight or a nine, which figures, if the two-pilot configuration was a seven. It was just a matter of how bad it's going to be. However, civil certification would be out of the question, except for in an extreme emergency. I am

talking about a real emergency — not any minor emergency. I'm talking about something like a . . . system failure, something like that.

Single Pilot: Continued Approach

It doesn't get any better. It still is an eight or a nine, somewhere in there. I guess an eight.

CONFIGURATION T15

Pilot M
Runs 40-42
Ratings: DP = 4; SPMA = 5; SPCA = 4

Dual Pilot

Overall, I would give this one a four, in that it requires moderate pilot compensation. I had no real problem in intercepting the azimuth with raw data. The cross-check required is very intense, I really had to use my cross-check from the HSI and various other gages in the cockpit. Maintaining the glidepath, I felt it was fairly accurate cross-checking that with the vertical speed indicator, and I was able to maintain it pretty close. Right down toward the bottom, I again had a very large correction to put in for azimuth and that took quite a bit of my attention so, therefore, I went slightly above the glidepath right at the bottom and was just a little bit late getting down to the minimum altitude.

No real problem with coupling. The aircraft response was good. The wing leveler — I did notice a couple of times. It did help me a bit, being able to center the stick, more from the confidence that the wings would come to the level position.

Workload on the pitch was quite, oh I would say, again, moderate. Small changes in pitch resulted in some fairly large airspeed changes and I was as much as 10 knots off either direction around 60 with this trim position of the attitude indicator.

No flight director and auxiliary tasks; overall from the cross-check requirement, the higher cross-check workload, I would give this a four.

Single Pilot: Missed Approach

I think on this one, I would give it a five, overall. The performance, I felt that there was no real problem intercepting the azimuth. Glidepath control was relatively good on that approach. The associated tasks — once I was stabilized — I think one of the real problems of the past has been trying to do some of the associated tasks without being stabilized either on glidepath or on azimuth, and I found on this particular run that speed control, especially during the turn, is very, very sensitive. If I was wings level and relatively stable, I was able to get the associated, the other tasks in the cockpit level with no real problem.

Again, the intensity of the cross-check that was required, I would say, was considerable and especially coming back after doing something else. No problem on the missed approach, establishing the climb straight out, having the information arranged in the cockpit as I do, having a plan in mind, I think really helped as compared in the past. Overall, though, I would say it required considerable pilot compensation and I would give that one a five.

Single Pilot: Continued Approach

Overall, I think I would give that approach a four in the workload category. I didn't feel that I was saturated as far as the requirement to do other things in the cockpit. At the critical time during the glidepath interception and tracking the glidepath, I think that most of the work had been done. I had everything set up at that time and I was able to concentrate strictly on the raw data.

From the cross-check standpoint, though, it did require moderate pilot compensation — again, using the other gages in the cockpit. Overall, no particular problems on that one. I always felt I was in control. I did have a little difficulty decelerating from the 80 to the 60 point at about the time the glidepath became alive and doing the two things at the same time required some rather healthy control inputs, but by being able to concentrate on the attitude indicator with my cross-check, I was able to do it. Overall, moderate pilot compensation and, therefore, a four rating.

Pilot G
Runs 57-59
Ratings: DP = 7; SPMA = 7-1/2; SPCA = 7

Dual Pilot

Okay, I will rate on this one. Okay, first of all, overall comments — the poor performance that I demonstrated on the run was anticipated from the free run and that is, I demonstrated poor airspeed control and poor glide-slope tracking. I got pretty well saturated in those two tasks, compensating for winds on lateral lineup, at least. All three were off; that is, glide-slope tracking was poor, airspeed tracking was poor, and azimuth tracking was poor. This is a fairly unsatisfactory combination here; the display and handling qualities.

For a rating, definitely its deficiencies require improvement for a dual-pilot situation. I anticipate, again, in the single pilot to have — to be close to disaster. However, there should be a learning curve factor, too. I will give it a good solid seven. Not much question about that. There was no concern of losing control, but I felt that adequate performance was not attainable on that run.

Specific comments — the intercept and tracking, I have discussed. All three were bad as far as the airspeed, glide-slope, and localizer tracking were concerned. I discussed those.

The lateral tracking was not a function of, or was not due to poor lateral directional characteristics per se, but as I've already said, but was primarily due to pilot saturation in coping with the vertical-tracking task, the glide slope and airspeed control.

As far as pitch and roll sensitivity and predictability are concerned, there was a lot of wandering around in pitch as I've seen in the past on these, on the gages, really hard to nail down a good pitch attitude for airspeed control. The flight director does help. One tends to chase the flight director a little bit, but certainly it stabilizes the pilot in the loop tracking task of finding a desired pitch attitude to maintain airspeed. This was not a matter of sensitivity, just a matter of the dynamics; maybe. Damping could have been better, certainly the static stability, which appears to be negative, is also a culprit there. Collective and coupling — I didn't see any problems in collective with the yaw axis. I did tend to stand on the pedal a little bit and sideslip it, but that's just a matter of getting used to it. Maybe more breakout in the pedals would have helped the yaw axis in this particular case.

Displays — no flight director — raw data only. With the control system we have here, raw data — it is really hard to hack it unless you go out and get a lot of practice. I would guess that with a lot of practice and familiarity with this particular configuration, a line pilot could shoot routine approaches down to the rig as I saw them today, breaking out. You wouldn't have to go a go-around although I performed a go-around maneuver without a lot of problems. I would say that it would probably improve and his opinion might move up to above a six and a half rating. It would be somewhere in the four to six rating. As I see it right now, I wouldn't give it better than a seven.

The raw data scan — I guess I already talked about that. That's what I had to do. Auxiliary tasks did not apply. I didn't see any special problems. I'll stick to my pilot rating of seven and that's the end of my comments.

Single Pilot: Missed Approach

Okay, on Run 58 — the first thing I noted here that I didn't bring out in my free run and in the dual-pilot run previous to it and it applies for the two IFR approaches. If the airspeed gets much below 60 the helicopter tends to really sideslip off to the right. I think I did just mention that, but it became a real problem in this particular configuration. A series of events, for some reason or other, I tended to get slow — never tended to get fast, did tend to get slow. I suspect that the divergence toward the low speed is probably greater than the divergence to high speed, once you are trying to track 60 knots, with respect to longitudinal static stability is concerned. So that is a big factor in this configuration. Once you slow down, the sideslip angle gets very high. This fouls up your localizer and heading control — excuse me, azimuth and heading control, and I really think it causes a major problem.

The pilot rating change, single versus dual, won't be much so, I can't go much further down the line here from a seven. Because of a lack of a flight director, the single-pilot and dual-pilot workload, it is close together. The handling qualities are really a problem without a flight director, and I was having just a little bit harder time with it trying to cope with frequency changes and communication workloads. However, I don't feel I was on the verge of losing control; definitely, it is a major deficiency. I will, therefore, rate this one a seven and a half, which is only a small pilot rating. I think that would show on our chart as to be no good for either, because of the handling qualities-raw data combination.

Going back on the other side, the intercept and tracking comments remain the same for dual pilot. The breakout and missed approach remain the same; however, when there are added piloting tasks, such as switching transponder frequencies and com changes, the errors that you build up in your trajectory control are a little greater, thus a worse pilot rating.

Aircraft response comments remain the same. I want to emphasize the added sideslip heading control interface problem there, again. Speed control was terrible, glide-slope control was terrible — once one gets off you chase that and then the others go to pieces. The typical pilot tracking task degradation there.

Displays — flight director wasn't used and those comments remain the same. Auxiliary tasks, I think I've touched on those already. The extra workload which the auxiliary tasks require of the pilot do degrade the tracking; although, there may have been some learning. Just to look at my performance, I wouldn't be a bit surprised if the performance was as good as on the dual pilot task. You are starting with a really degraded situation and it can't degrade much more than it is, except on the verge of losing control. No other special problems, and those are the end of my comments.

Single Pilot: Continued Approach

Okay, on Run 59, still a bad combination of display and handling qualities here. I'll stick to my rating, in fact, of seven and a half. I would like to change the two single-pilot ratings to seven and a half to eight. I want to change them both to seven and a half to eight. Here, again, the missed-approach procedure workload did not seem to make a great deal of difference. It didn't push the task here over the line from an unsatisfactory; that is, an inadequate performance to a concern about control — borderline there. So, that's why I'm calling it a seven to a seven and a half. However still, again, a bad combination whether single or dual pilot. Again, the big thing I saw was the pitch axis, the airspeed control was very bad. Once one starts to overcontrol in the pitch axis, the glide-slope tracking goes way off, in comes some fairly large power changes, collective changes, and the whole tracking task just goes really bad — almost divergent, but I never felt I was going to lose control. I checked my altitude. There was never any real concern of losing control of the airplane, although I was doing some needle chasing.

Again, once you get below 60 knots it is easy to do. I tried to hold my airspeed a little on the high side this time and got up to 80 knots a couple of times; but, it also went down below 60, the sideslip came in, localizer tracking got bad. Azimuth tracking, excuse me.

Those comments are loud and clear now to me.

Looking at the back, I don't think there's any need to discuss those any further. My specific comments remain the same as in the previous single piloted run. Those are the end of my comments.

Pilot K
Runs 236-238
Ratings: DP = 4; SPMA = 5-1/2; SPCA = 5-1/2

Dual Pilot

First off, I would say that this one was an acceptable two-pilot thing. I don't know what happened in the final stages. Had it not been for the final, down to about 600 ft, I would have given it a different rating; but, at 600 ft, I think my cross-check wandered in glide slope. I didn't like that one bit. Primarily, that's what my rating is going to be based on; the excursion below glide slope and approaching minimums.

The overshoot didn't seem to be all that critical for this approach procedure, including turns both left and right. I just tried the right turns to feel it out. Although I would say that it is acceptable, I wouldn't give it a satisfactory for two-pilot, in this case. Unfortunately, I think, based just on that one excursion, approaching minimal to well below glide slope. Also, at this time, my cross-check wandered and I was right of the localizer.

I would have to give that two-pilot task — it certainly warrants improvement, it took moderate compensation. I will give it a four for the two-pilot task.

Single Pilot: Missed Approach

The interesting one on this one is that it's much like the two-pilot thing. Whether it is the turbulence levels or the tightening up on the . . . of the MLS — the final stages of the approach is where everything seems to . . .. It's clearly not very nice at all. This time, too, it included part of the missed approach. Some fairly hefty speed excursions on the missed approach.

Basically, I think the speed excursions to, what I feel, possibly a pitch speed coupling is a little bit sloppy — it appeared as though I had changed my pitch angle and I would have to wait for the speed a fair length of time before it came, and then if I was lax on my cross-check, it would overshoot the desired speed I was after. However, I would say that this one, bearing the critical parts in mind; the excursions were rather large. I would have to say that it required considerable pilot compensation.

It is acceptable, and the performance was probably adequate — just adequate with considerable pilot compensation. I would have to give that a five.

Single Pilot: Continued Approach

This one was probably — the past performance in the final stages — the approach was marginally better; but, I still don't really like it. In fact, I would like to give my last rating a five and a half, but if I can't, I'll give this one a five and a half.

CONFIGURATION T16

Pilot M
Runs 34, 35
Ratings: DP = 4; SPMA = 6

Dual Pilot

I would say that this required moderate pilot compensation. I would give it an overall rating of four. Just from the workload and having to split my attention between the raw data for the azimuth information and the collective command information on the upper command bar. Again, I was able to compensate for any lack of the horizontal bar by cross-checking attitude, especially intense. No real problem maintaining the glidepath. I seemed to "S" turn down the azimuth several times. I would make a 5° or 10° correction and it wouldn't be enough and I would put in a little more, and about that time, I must be hitting winds here of some kind. So, therefore, I was getting about, oh, a one-dot deviation of the azimuth information on the raw data bar.

Overall, I would say that the increased pilot workload, just from the cross-checks required, and the fact that you are now using two gages rather than one gage or one consolidated flight director system, would downgrade this to a four.

Single Pilot: Missed Approach

Okay — overall, I would have to give this one a six, in that it required extensive pilot compensation, primarily, with the associated tasks. Just flying the aircraft was no real problem, but I found that when I was distracted again, going through the additional tasks within the cockpit, I had to really concentrate on maintaining the aircraft attitude or aircraft control.

The missed approach, this time, didn't appear to give me as much problem; although, I did have some pretty big attitude excursions. As I would check the transponder or check the — primarily the transponder, looking down into the side. That gave me the most problem, but I was able to come back and recover the aircraft. I think this one, compared to the last single-pilot IFR; I did a plan in mind, which was to climb to 1500 and a heading of 080 and once established on that during the associated tasks of tuning the radio and calling for the further clearance. I think that is real important on single-pilot IFR, especially.

Overall, just because of the pilot workload, the number of places you have to look in the cockpit, the switching of the hands, the writing of the clearance, I would have to give this one a six, in that it required extensive pilot compensation.

Pilot M
Runs 43-45
Ratings: DP = 5; SPMA = 4; SPCA = 4

Dual Pilot

Overall, I think I would have to give that one a five, particularly, because of the pitch axis. I was really having a lot of problem, considerable trouble, maintaining my airspeed and possibly because with the collective director, I was using that to make the power changes and really, the thing that was left out of my cross-check was the raw data glidepath. So possibly, the sensitivity of the collective director caused me to make more power inputs, a lot more small power inputs, than I would have had had I been on the raw data glidepath. That would be relatively insensitive compared to the director.

Overall I found that the cross-check going from the ADI to the HSI caused me considerable workload so, overall, I would say that there was considerable pilot compensation required and would give it a five. No real problem on the azimuth except when my cross-check or fixation was on the pitch axis, and I really had to concentrate on that and then several times I was a little slow correcting the deviations on the azimuth indication on the raw data; but, no real problem once I saw the deviation — I was able to get back to it. Overall, a five though.

Single Pilot: Missed Approach

There was no particular problem on that run in the expansion of my cross-check to the raw data on the collective command. I was able to anticipate and I seemed to have less problem with airspeed on that one. Slowing down the work in the cockpit and just stabilizing the aircraft first really helped. Again, having the information here readily available, helped. No particular problem on the intercept. The glidepath — I felt was fairly accurate. The azimuth — no large deviations, in fact, I felt I was pretty tight on the azimuth deviations on that one. At one point I felt as though I had a heading pegged that was giving me very little deviations so, therefore, I was able to expand the cross-check a little further.

The missed approach, copying the information, again taking it very slowly and doing what was necessary. No problems with aircraft control. No problems transitioning and turning to the heading. A few times during the climb-out after the turn, I did have one airspeed problem, but no large deviations. I felt I was completely in control all the time. Overall, just from the cross-check required, I would give that a four.

Single Pilot: Continued Approach

Overall I would give that one a four, rating from the cross-check — many of the same comments, although I seemed to have less problem with the airspeed on that particular run than I did on the previous run. Just from the cross-check required, I found that I expanded my cross-check a little bit on that run, possibly the learning curve and started using the glidepath raw information, raw data somewhat to anticipate what the collective command tab was going to do, and I found that settled it down rather than just flying the command tab itself. That seemed to help both on the pitch and the application of the pitch changes and the maintenance of the airspeed.

At one point, I did drop about 10 knots, but again, I was able to readily correct for it. Overall from just the workload standpoint, I would say that it was moderate and I am giving it a four.

Pilot K
Runs 239-241
Ratings: DP = 3; SPMA = 5; SPCA = 5-1/2

Dual Pilot

The difference in this one, really, in giving me a collective cue, is on the collective cue; useful, in that it was a different presentation. A relocation of my glide-slope indicator. I found my cross-check was considerably improved.

My localizer tracking in the final stages — when it did get a bit sloppy, it was simply because I was finding I was a fair bit more relaxed and I just let it go. It is not really indicative of my workload; but, certainly an improvement, I felt, mainly because of the relocation of my collective control demand cue.

It is certainly acceptable for two-pilot; in fact, it is just bordering on satisfactory without improvement. In fact I am split as to whether I should make it satisfactory or not, it's pretty on . . . bordering there. I will have to give it a three for the two-pilot. So, that is satisfactory.

Single Pilot: Missed Approach

I probably did get some help from the collective cue — the MAI helped my cross-check, per my remarks on the two-pilot task. However, I did find on this run that I had a considerable amount of pilot workload, not necessarily in the . . . channel, but I certainly would still like some improvement in the pitch channel. The airspeed control was the main problem. I would say that this is probably acceptable for single-pilot IFR, but unsatisfactory, mainly because of the workload required related to pitch control. You really couldn't let pitch alone while doing auxiliary tasks.

There is considerable pilot compensation so, I would have to give this one a five.

Single Pilot: Continued Approach

As with the previous run, it is acceptable, but unsatisfactory — unsatisfactory, in that I felt that the collective cue, although I liked it better as an air indication for glide-slope correction and it is convenient near the MAI, I felt that, possibly, if it were located up there, it may be detracting from my glide slope. I felt that I might have been missing my glide slope and some of my — correction, I might have been missing my localizer in some of my cross-checks, because I felt that my localizer performance was a bit "wishy-washy."

My comments are not much different than the previous time, but I would say it certainly caused considerable pilot compensation because of the final stages, the gross errors in the final stages on the approach. I will have to give this one a five and a half.

CONFIGURATION T17

Pilot M
Runs 30-32
Ratings: DP = 3; SPMA = 8; SPCA = 3

Dual Pilot

Okay, I would have to give that one a three, in that there was just a minimal pilot compensation required. Again, the two axes of the flight director were very helpful. Any deviation I could readily see, both in either the collective or the lateral cyclic, where to go. Without the horizontal bar I was able to pay a lot closer attention to pure attitude of the aircraft without having to look through the bar and without over controlling, and I found that very small attitude changes were required in order to change the airspeed. It appeared as though, probably, the same attitude, as far as what I see on the attitude indicator, was required for 80 knots and for 60 knots.

No real problem on the intercept or track. On this particular run it seemed as though there was a pretty large intercept angle generated by the lateral command bar; but, it was very gentle. There was no real rapid inputs that were required.

No problems with the aircraft pitch and roll. No noticeable adverse collective coupling on this one. On the display, the sensitivity seemed good. The response seemed excellent. Of course, no auxiliary tasks and no special problems. I didn't even hit the reset on this one. Overall I would give it a three.

Single Pilot: Missed Approach

Okay, let me see here, overall I think I would give this an eight for a particular reason that I will get to.

Overall the task was very comfortable as far as the interception. The glidepath down to the major portion of the approaches with the associated tasks — there was no problem getting to the radio and chenaing frequency, decelerating to my 60 knots, picking up the glide slope. Again, it was very helpful — I was able to precisely control the pitch attitude. I had to control the pitch attitude in order to maintain a precise airspeed.

The problem came in on the go-around mode. Let's see, the requirement for a left turn given by the go-around mode and it was pretty well established. Again, I lost track of the pitch attitude as I was reaching, going over and changing frequencies. Airspeed continued to deteriorate, and I was unable to recover it by making what I felt was appropriate inputs to recover. In other words, I realized I was turning and I flat couldn't stop it as far as picking up or increasing the airspeed again. So, I would say that on the missed approach, the division of attention, losing the pitch attitude, the reference was considerable pilot compensation required for control. I think I might possibly have recovered it had I noticed this a little earlier and I, well I, put a little more emphasis than I should have, probably, on tuning the radio. I should have recovered the aircraft first. I think there might be a slight procedural problem here on this go-around mode, because that requires a left turn or commands a left turn and there's a . . . amount of time between the time

you start the missed approach and the time you call approach control. I think what might be appropriate would be to start the normal published missed approach and then at least get established on that radio. If there was any amendment to the missed approach, then at that time, do it. All I was wondering about that time, which I think I will correct next time, was following the command mode and was making my left-hand turn. I think this distracted me, also, the fact that I was in the left-hand turn, wondering what the missed approach or the amended missed approach was going to be, and at the same time, tuning the radios. Overall, I would say that that was an eight. I think it could have been recoverable. I don't think if my cross-check would have been as it should have been, that the control would have been lost so, therefore, I think that it would have taken considerable pilot compensation for control, so I've given it an eight.

Researcher: Okay, we should have made it clear that it's your choice of putting the flight director in the mode of your choice during the missed approach and selecting the direction of turn.

Pilot: What happens, though, is I think — I did put it in and I made my turn to the left and the missed approach for that one is a left turn to 2000 ft, and again, it was just my division of attention. I wasn't oriented towards going to the white lake VOR at the 070 heading, but I think next time that will be what I am shooting for. I hadn't planned far enough ahead. That's why I think that part of that problem right at the end was me and a failure to plan ahead rather than the system or the conditions here.

Researcher: I think I understand. I also think that maybe we should encourage you to continue with the published missed-approach procedure and the dual-pilot missed-approach part of that run so that you will at least see the aircraft in the flight director, dual pilot . . . the added auxiliary workload.

Single Pilot: Continued Approach

Okay, overall, on that one, I would have to give it a three. I think I am getting more used to monitoring the pitch attitude of the aircraft and anticipating the decelerations from 80 knots to 70 knots. No problem on the intercept or the tracking. I decelerated at what I felt was the correct place, to 70 knots before I started the glidepath. No real problem maintaining the glidepath. No real problem maintaining the glidepath, even during the associated tasks. The aircraft reaction felt excellent. There was very little coupling, if any, and overall I would have to give that a three for that particular task — no problem.

Pilot G
Runs 207-209
Ratings: DP = 4-1/2; SPMA = 6; SPCA = 6

Dual Pilot

The problems that I anticipated, sure enough, did show up. The lateral tracking course for the flight director was good most of the way. There was some tendency to ride on a pedal and put in a little bit of sideslip; with a good old sideslip meter there, the information told me to get my big, fat foot off that right pedal. The only tracking problem and the highest workload, of course, was associated with the

pitch axis. I did notice a thing that's quite expected, I guess: that one must be careful in making these corrections for airspeed error. You have to be quite careful — if you put in too much pitch attitude, either way, it really gets you off on your glide-slope tracking, but you have a collective director here to tell you that right away. It responds quite quickly, but the amount that you get off in glide slope is quite pronounced. If you make a — see it get near the bottom, your minimums, and push the nose a little bit too hard due to maybe a lack of pitch-attitude loop, you might push yourself down well below the minimums — so that could be a potentially dangerous situation.

The pilot rating for that — certainly it is better than a six and a half, but not a three and a half or better, for the abvious reason. We have a rate, rate only in pitch and we have no pitch flight-director. However, for dual-pilot operation, even with the missed-approach procedure, I feel that adequate performance is attainable. However, the objectionable part would be the fairly high workload. I think there's a potential there to, maybe, get in trouble down close to the water, as I've indicated.

I will give you a pilot rating here when I get squared away. I will give it a four and a half for a pilot rating, and then on the other side of the card here; the intercept and tracking — for the azimuth, of course, was good. The intercept of glide slope was okay with that flight director in there. The only problem I had was during my scan the airspeed got a little slow once and I over corrected a little fast and went through that oscillation there, trying to correct for airspeed. The glide-slope error built up. The flight director helped me to get back on. If I had been single-pilot there, I think, I could have maybe gone and maybe precipitated fairly large errors in the glide slope. If I had my eye on something else, doing some auxiliary task, so I would anticipate that on the single-pilot runs, here.

The breakout and missed-approach maneuver — no special comments other than the ones I have made on that. The transition was straightforward and no problem. This was a turning missed approach and I had a turn flight director there to help me do that.

The pitch axis was manageable with the high power as long as I had full attention on my scan. Okay — aircraft response, pitch and roll, sensitivity, predictability, were — no special comments. They were okay. Same with the collective, but I didn't see any collective coupling in the short term. I did pick up some in the long term during the free run. Yaw axis behaved itself okay. The roll and the collective flight director system certainly reduced the pilot workload considerably, putting it above a six and a half by an appreciable amount. The pilot sensitivity and response to that was good. The raw data scan was — I was able to do that without any undue high workload.

Auxiliary tasks do not apply, and that's the end of my comments.

Single Pilot: Missed Approach

On 208 — This single-pilot task certainly was sensitive to the auxiliary duties in the cockpit as far as pilot rating is concerned. While trying to, I guess I have to qualify that a little bit. I had a display problem here but, nevertheless, the airspeed and — I guess it was primarily airspeed control that was a problem during the copying of the clearance and the changing of the frequencies here. I got a little

concerned for my control of the attitude of the aircraft. Nothing dangerous — nothing bordering on uncontrollability, but nevertheless, really undesirable.

Okay, to go back, and get you a pilot rating first. I will give this a six to a six and a half.

Researcher: We can copy a six.

Pilot: Okay, a six, huh? I may want to change that, I'll go on and give you my narrative now. Okay, on the task performance — the first part of it went pretty good. In fact, right down to where I had to make my missed approach point decision.

The cockpit duties were relatively light; primarily, reaching down and chaning the transponder code, I believe, so I was able to keep the instrument scan going there for most of the period, and it was a relatively reasonable workload. I assessed my performance down to the missed-approach point was pretty good, very much like the dual-pilot case. Down to there, I would rate it the same. I think a four and a half is what I gave you before.

The problem, of course, came in the high cockpit loading here during the missed approach and the clearance. The tracking of airspeed was poor. Once I was able to get back to full-time instrument scan, I got on the VOR radio okay and got the airspeed squared away.

I mentioned the breakout — excuse me, the missed-approach part. That was the only place where tracking was a problem, and that is in airspeed. Okay, aircraft response — no further comments other than those I have already made. I didn't see anything new there. Of course, the pitch axis is the one that can get away from you and it did in my case here as I looked away.

Flight director — again, the lateral flight director was very helpful, both in azimuth tracking, coping with the crosswind, and executing the missed approach left turn that's published. Also, the collective flight director was helpful in maintaining glide slope. I made it a point this time to really anticipate glide-slope changes, making pitch-attitude changes for airspeed corrections, and I purposely made those pitch-attitude changes very small and anticipated collective change requirement and that really helped to do that — the technique I had to use.

I feel that a single-piloted aircraft pilot should not have to do that. I feel that that is a little bit more than you would want to give him for a system that is to be marketed, or certified, I should say.

Raw data scan, there was no problem there other than taking the clearance and changing the frequencies, of course. I had to take my eyes completely off the panel for periods of time.

The auxiliary tasks, as I said originally, at the beginning of this commentary, caused a high workload and a deterioration in my tracking performance.

Now to get back to my pilot rating. I am going to give it a six, and I don't know, as far as the certification goes, it bothers me a little bit. If we say that a six is certifiable for single-pilot, then I want to change my rating to a seven.

If we say it has to be a three and a half or better for single-pilot certifiable, then I would go ahead and leave it at a six. I will throw the ball back to you.

Researcher: Okay, we copy that. I think that the line where the certification is, it is still kind of flexible. Listening to Pilot S, it sounded like anything worse than a five would not be certifiable, and anything better than a five would be regardless. You know, given the rating for the task, so if that makes you happy with your six.

Pilot: I'll rate it a six to a six and a half and you can put down a six for the computer there.

Single Pilot: Continued Approach

Okay, on 209, even though the workload a far as auxiliary tasks was lessened by lack of having to fly the missed approach and copy the clearance, my tracking on this particular MLS approach was poorer than the first one. Airspeed got low and I got — did some deviations, which induced some deviations from the glide slope. I was able to get back on okay, but I just don't like the way you can — the airplane can't diverge in airspeed. However, you can still shoot the approach and with the discussion we had on the last run, where maybe something that's certifiable has to be a five or better, then I would; I feel there is adequate performance for the approach with extensive pilot workload. That probably describes it pretty well. I will give you the same pilot rating of six and I don't think there are any other comments that are in addition to my last single-pilot run. Just go ahead and record a six and that will be the end of my comments.

Pilot M
Runs 302, 303
Ratings: DP = 4; SPMA = 5-1/2

Dual Pilot

No, let's go ahead and rate that one. Overall, I think I would give that one a four there. Moderate pilot compensation. I found no real problem with the localizer and intercept or tracking. I was able to follow the command needle very easily. The biggest problem was in the pitch axis and cross-checking that with airspeed. I had some pretty large airspeed excursions, as much as 10 or 12 knots. Again, changing the attitudes caused a — essentially, almost a coupling effect on the vertical axis, which increased the activity significantly in the collective command bar. I was able to maintain a relative precision on the glidepath, so therefore, performance overall was satisfactory. However, I think the moderate pilot workload in maintaining an airspeed and keeping the pitch axis, the pitch in attitude, somewhere close to center, would cause me to give that a four.

Single Pilot: Missed Approach

Overall, let's give that one a give and a half. Mainly because of the pitch axis. Anytime my attention was distracted from the attitude indicator mainly maintaining a relatively precise attitude, I would usually get some large excursions in

both attitude and in airspeed, although I was able to maintain and track the localizer with relative accuracy. I think I was within one dot on the glidepath; however, I really felt that the overall workload in maintaining the pitch attitude and the airspeed was considerable.

The missed approach — I really had to take my time on it and, if time would have been a factor, it really would have been an extensive pilot workload. So, overall, a five and a half.

CONFIGURATION T18

Pilot M
Runs 46-48
Ratings: DP = 4; SPMA = 5

Dual Pilot

I think this one, for a different reason, I will also have to give a four. Moderate pilot compensation was required and I seemed to have quite a bit of difficulty in the pitch axis, quite an active control system of pilot inputs. Very high control activity, especially in the pitch axis. I felt that several times I was approaching almost a PIO situation and I had to go to the . . . the attitude indicator and sort of anticipate what the command bar was going to do based on where I was and expand the cross-check down to the raw data. So, therefore, it could have caused a little more of a workload than having a pure flight director system that you had a great amount of confidence in. I did have to go to the raw data to back up the flight director and anticipate what the flight director was going to do for me. Based on that, it required a moderate pilot compensation; that is pilot effort and pilot workload, pilot control activity — overall a four.

The elevation command bars in the go-around mode on the center position. We were getting a real large fluctuation on the DME indication and a lateral deflection on the azimuth on the raw data.

Single Pilot: Missed Approach

I think that one would be a five as there was considerable pilot compensation, mainly again, for the pitch axis and the sensitivity of the command bar as they caused quite a bit of control activity. Many of the other comments remain the same. I was able to dampen out some of the effects of the command bars by going to raw data.

No real problem obtaining or attaining or intercepting the azimuth. Glidepath, I really had some deviations again. I felt almost that I was approaching a PIO situation; therefore, that took quite a division of attention, quite an amount of attention on the pitch axis. The missed approach. I began a right turn and when I got the modified clearance I rolled out on the heading of about 060 and continued to climb ahead and at that time I started having the problem. When I tuned the 115.2 in for . . . pass, I was getting quite a deviation on the needles and the command bars during the go-around mode. It just went to the full-up position and full-right position. So, I just went back to basic attitude indicator and raw data in order to conduct the missed approach.

Overall it required considerable pilot effort on my part, both on the control activity and the pitch axis, and with the associated tasks; especially having something go slightly wrong, I gave it a five.

Pilot G
Runs 60-65
Ratings: DP = 5; SPMA = 6; SPCA = 6

Dual Pilot

This has been a very interesting progression holding the handling qualities the same and then going on to a more sophisticated display. The big thing I noted is that my azimuth tracking was very good despite some sideslip tendencies. It was right on, which shows that the lateral axis tracking was improved just by putting a needle in there. The handling quality was good laterally. It was just a matter of giving the pilot some information to help him, even though I was distracted somewhat by the pitch-attitude task. The lateral task did not break down, and that's a good classical demonstration of piloting aids and what they can do when you are starting to get saturated on one axis. That's the first thing I noticed. The second thing I noticed was an overall expected improvement in the approach with regards to airspeed control and a thing that goes right with it because of the pitch-attitude tracking task is height control. Less chasing with collective, more preciseness on staying on glide slope and a little bit lower workload. However, the poor pitch dynamics and statics still predominate. That is certainly the deficiency that warrants improvement. So, this cannot be given a three and a half or better. However, the performance of the task was, I think, adequate enough in dual pilot, so I am going to give it a rating somewhere between a three and a half and six. I think I will sink it into a good old five, center of the deal there.

I've talked about general impressions — going to specific comments on your sheet here. Azimuth intercept was good because the lateral dynamics and flight director were there. They were good. The breakout and missed approach weren't too bad either. There was no requirement other than to hold airspeed on that turning missed-approach. The airspeed control still was kind of poor, but it was better than with the raw data. There tends to be on my part a little bit of flight director chasing here. You know, it might be interesting to look, if we ever have time, to look at the difference between the flight director on and off for that missed approach. If you just pick an attitude and hold it, you might have better speed control. You may not tend to overcontrol in the missed-approach pitch attitudewise or maybe the pitch flight-director laws could be changed a little bit more. I don't know, it's just a confusing statement I just made there.

Aircraft response, I think I've already talked about that enough. No problems in collective. Again in yaw, this horrendous sideslip tendency. My speed control was better this time; although, if you get less than 60 it really starts to diverge and sideslip. Because of pitch flight director my speed control was better, so I had less problems with sideslip divergence and thus, again, lateral tracking was also improved from that point of view.

The display, I think I talked about that already. The effects of flight directors brought me back to almost highly desirable in the lateral tracking. There are still some problems in pitch due to the characteristics of the aircraft. Auxiliary tasks don't apply and that's the end of my comments.

Researcher: Did you comment on the director in the missed approach mode?

Pilot: Yes, I did a little bit, I alluded to it. The lateral steering was good. Again I had some problem with holding. There's no collective flight director to follow in the climb. If you do follow it you can overtorque. I just put in about 95 percent. The speed control is still, I'm still chasing the speed control bar due to the . . . longitudinal dynamics and statics of the airplane. That's my comments there.

Single Pilot: Missed Approach

The flight director really helps. Things were going along pretty neatly except for some airspeed — some variations in airspeed and glide slope. Nothing like the raw data situation previous to it. I was able to handle the auxiliary task here in the cockpit, able to look away from the panel and then look back and still maintain pretty good trajectory control here with the use of the flight director needles.

The pitch axis is still a tough one to cope with, but by the addition of the pitch flight director bar and lateral flight director bar, in particular, it helped you to get back into correcting the attitude if it does wander off. In this case, in pitch. So, a little bit of sideslip problem again, but that's tamed down considerably with the addition of flight director. Again, a tendency for the helicopter to get slow in the case of my control of it.

Similar type of impression here. I feel that the approach was somewhere down below a three and a half and, I think, adequate though. I feel that that trajectory control was considered an adequate performance. I am also keeping in the back of my mind what the average line pilot would do when in practice and in training on this particular configuration. So, I am going to rate it a six. It is rated down from five from the single-pilot case because of the effects of the added workload of auxiliary tasks.

The same comments as far as the handling qualities and the addition of the flight director and the effects, thereof, apply as discussed in the earlier runs. I think that's the end of my comments unless you have questions.

Single Pilot: Continued Approach

The configuration did look familiar with the same one that I picked up or I should say, that I looked at last time, so I think the computer is doing the same things. Again, it was quite obvious and it was demonstrated I think on my approach. There was one point along the approach down towards the minimum point, maybe about 300 ft above, where the pitch attitude got away from me a little bit. I went well below glide slope and I latched right back on the flight director needles and zeroed right back up on the glide slope and localize azimuth again. Again, the combination of handling quality, the control of systems sophistication is poor, and a good flight director, which sort of saved the day there. However, because as I mentioned before, it's easy to be distracted and easy to let the pitch attitude get away from you, I would not want to rate this a satisfactory or even an acceptable combination from the handling qualities point of view.

It did pass the test for adequate performance, but very marginal. I will rate it as before. I think I gave it a six. I would like to drop that down from a six to

a six and a half, for that particular reason. I think I talked about that on the previous evaluations, the poor attitude — pitch-attitude control which reflects in poor airspeed and glide-slope tracking. It couples into it and causes some rather large power commands on the flight director. I don't think I will go any further on this — in review of my other comments, they still apply.

Pilot K
Runs 242-244
Ratings: DP = 2; SPMA = 4; SPCA = 4

Dual Pilot

I noticed a marked improvement — I think the performance increased, but what is even much more important, the improvement is a very slight increase. I think my workload was considerably less. For two-pilot work, it certainly is acceptable, it is certainly satisfactory. I would have to give this one a two, simply because the main help was the pitch director cue in maintaining my speed for me.

Single Pilot: Missed Approach

On that one, I was all set to give it a fairly good rating until I came to the missed approach. To me, the missed approach is the most critical part, most critical in that although I felt that the flight director was fairly useful in tracking speed . . . the pitch attitude as the aircraft . . . the pitch control of the aircraft left a lot to be desired when I took my eyes off the flight director — off the MAI. I could always glance back at it and the flight director gives me a good indication of aircraft performance state and control demands.

However, what I didn't like was the pitch excursions that I could get to when I did take my eyes off the flight director to tune radios, and so forth. So, that one will be acceptable for single-pilot operation, but I feel not entirely satisfied because of the pitch channel. I would like to say that it is a four. It still requires moderate pilot compensation.

Single Pilot: Continued Approach

Generally, the — it is certainly improved. I think the flight director reduces pilot workload. The big thing is that if you get away from your cross-check, you can always get a quick glance and very quickly get the axis aircraft state. However, on that one again, what I didn't like, was that when I did get away from pitch-attitude control when I would go in to glide slope — the flight director for a short while, tuning radios, and so on, when I got back to it, I was fairly unhappy with the excursions that I saw on the flight director.

The corrections seemed a lot easier to make with the flight director information, but the excursions make me feel that this is probably acceptable for a single-pilot, but certainly not satisfactory. Again, I would have to go with a four for this one.

CONFIGURATION T20

Pilot G
Runs 165-167
Ratings: DP = 5; SPMA = 6; SPCA = 6

Dual Pilot

I think there is some learning in here. I think I did better without the flight director. There's one point, though, where I think I did scoop below the glidepath. I think the only comment besides the pilot rating, which should refer to the flight director. I really didn't miss the collective flight director, although, on the first set of approach, I said it was helping. I believe there is some learning here in sorting out the power setting for the descent; it certainly helped. I was able to stabilize on 600 ft/min pretty well. Let me give you a pilot rating for this thing without the flight director, then we'll get on with the single pilot's. I am going to give it a straight five. I realize I gave you a five and a half on the other one, but you put a note on there that I think I did better because of the learning aspect. There are no other comments, we will go on to the single pilot.

Single Pilot: Missed Approach

The added cockpit duties in taking the clearance, and so on. During that time the pitch attitude got upset — I guess I leaned on the stick or something and the airspeed got slow. However, that's all that happened. There was no divergence off due to that. Certainly not satisfactory for single pilot; that is, it is not better than a three and a half. Again, I feel that even with no flight director, this is just a marginal or a passable situation here. I want to give it a six to a six and a half. We can go on to the next approach while the time is available.

Single Pilot: Continued Approach

The beginning of the approach looked real good, real smooth. I got on to the azimuth and on to localizer — excuse me, on to the azimuth and the glide slope very nicely and started concentrating on what the power change would do to speed. It looks like maybe the nose dropped a little bit and the airspeed picked up a little, which means there may be a bit of coupling coming in there. That might be the problem that I've been looking at all the shile. Is this a decoupled helicopter, it should be if its got attitude?

Researcher: Yes, it is.

Pilot: It looked like the nose — anyway, it looks like the airspeed picked up a little bit as I dropped the collective and that might be why I'm having some trouble with airspeed control. Everything looked fine until, I guess I fell asleep, or something. I got way above the glide slope, however, had minimum as I broke out. I was pretty much established in and on — went in and executed the flare to land.

This configuration bothers me. I know that it should be better, but I cannot seem to make it do better things. I feel, again, the flight director is probably the missing thing and, certainly, is better than a six and a half, but not as good as a

three and a half, so it stays down here in the in between region. I am going to — did I give you a six to a six and a half last time?

Researcher: You gave us a six on the last approach.

Pilot: Okay, I am going to give you a six on this one, as well, and for the same reasons here. That ends my comments.

Pilot K
Runs 182-184
Ratings: DP = 3; SPMA = 4; SPCA = 3

Dual Pilot

Okay, on that one it was a fairly pleasant model. No doubt I was missing some cues after being spoiled by a flight director. However, the difference is not all that noticeable. I found without the flight director, my azimuth task had certainly increased, and also the longitudinal task, the tracking, speed, and the glide slope. Probably, with this one, I found that the display is fairly important; mainly the location, as far as my cross-check is concerned. The location of the HSI on the bottom and the airspeed up at the top. I found, probably, a good portion of my workload was because of that rather gross scan, where I had to scan across a few instruments that I wasn't interested in. However, it was a minimal pilot compensation required for desired performance. I would have to give that a three.

. . . aircraft stability, unfortunately, but I found the aircraft quite well behaved. Unfortunately, relating to my instrument scan here.

Single Pilot: Missed Approach

That one, also, was fairly pleasant for the single-pilot task. A little bit of attention from the control task was required to do the auxiliary tasks. Just one little comment: I've got a VOR set thing that should settle between the numbers now, the first three numbers. It looks like one of the digits slipped on the frequency selector.

However, the aircraft was pleasant, much the same performance as the two-pilot task. It was more of a display problem. The localizer tracking and the glide-slope tracking, speed was probably made a little bit more difficult because of the cross-check required.

For that one, I would — that's awful close to being single-pilot IFR. Give it a four, a fair rating. It required moderate pilot compensation, although I could surely see that if I had a good night's sleep, I might give it a three.

Researcher: You say it's close to being satisfactory?

Pilot: Yes, I would say it is very close. I would like to give it a three and a half, but you guys won't let me.

Single Pilot: Continued Approach

Okay, that one was much like the missed-approach one. The same comments on what I found to be a very well-behaved aircraft, well-behaved model. It still requires a minimal to moderate pilot compensation. I am going to commit myself. I am going to give it a three which will be satisfactory. It will be on the satisfactory side.

Pilot S
Runs 200-202
Ratings: DP = 3; SPMA = 3; SPCA = 5

Dual Pilot

On that configuration, during the approach, call it a three. There's some pilot compensation required, but it is not all that bad.

Single Pilot: Missed Approach

That's a three. I got off of heading and was making some big excursions, but that really was my fault. I found myself, even on the missed approach, when I was handling — doing the radios — that I really wasn't paying all that much attention to the machine. I did drop airspeed, but that configuration really isn't too bad.

Single Pilot: Continued Approach

. . . the additional workload of the single-pilot. Seems to get airspeed excursions and takes a little bit more attention. That changes it from the previous rating of a three to a five. It requires considerable pilot compensation just to keep on.

Pilot M
Runs 278, 279
Ratings: DP = 4; SPMA = 4

Dual Pilot

Overall, I think I would give this a four, moderate pilot compensation. I was able, again, to intercept and track with a relative accuracy both in the glidepath and in the azimuth until I got down to the bottom of the approach and, then, overall I would say that the aircraft response to a deviation and a control input on my part, seemed just a bit sluggish to try to correct a large deviation. With small deviations, I didn't have any problem whatsoever in maintaining precise control; but, with the large deviation, I did have trouble getting back to it. I would say that it just required moderate pilot compensation. I think I could adequately do the task and I would give it a four.

Single Pilot: Missed Approach

Okay, that was a comfortable approach. I had no problem intercepting or tracking either in the azimuth or the glidepath. With this particular control system, I was able to deviate my attention from an intense cross-check with no real difficulty.

Tuning frequencies was no problem. Large deviations — again the same comment, I think that I made on the previous run; that any large deviations required quite a — seemed like quite a large control input in order to make a correction, but easily controllable, no control problems other than that. Even during the missed approach, I was able to establish a climb and as long as I didn't make any inputs, it was a relatively stable climb-out, and I was able to copy the clearance. When I did tune in the 115.2 and I had the problem, I was able to, in a trimmed condition, go down and get the actual approach plate and confirm my frequency on that. Again, it allowed me to do some additional tasks within the cockpit with no real problem.

I think, overall, it required a moderate pilot compensation and give that system a four also.

CONFIGURATION T21

Pilot G
Runs 161-164
Ratings: DP = 4; SPMA = 5-1/2; SPCA = 5-1/2

Dual Pilot

The first general comments are that it was a little bit harder to fly than I anticipated. I had some problems in maintaining the longitudinal axis where I wanted it. All three — the glide-slope tracking, the airspeed control, and the azimuth control — all three of them worked real good, as good as I anticipated they would be with this flight control system.

I would like to make another one — I don't know — why don't I fly one more, because I am concerned about the learning deal here. Let's go ahead and let me fly one more.

Okay, I made a second run for this first dual-pilot case. I did a little better in my own assessment of my performance, but still there was some glide-slope error down towards the minimums and airspeed got 5 knots high one time while making a glide-slope correction. So, I feel that this — I guess what I'm saying is I probably missed the pitch and roll flight director here, even for the dual-pilot case where I could concentrate completely. The airplane does have obvious attitude loops in pitch and roll, but the airspeed doesn't hold real well — the fact that the pitch axis is fairly well stabilized. The airplane does tend to wander a little bit, and the speed changes, probably with collective; making collective changes causes some speed changes, requiring me to do a little bit of change in attitude to correct the speed error. The flight director for power was certainly a help, although I did miss the pitch and roll command bars.

Pilot rating-wise, let's see here, I will give it a three. As far as task performance goes, I did overcorrect for my tracking, I went through the azimuth, out the

other side. I never did have the azimuth really nailed all the way down. It was a little poor. The glide-slope tracking was assisted by the collective director — power director, but there was some errors on the glide slope, as well. Chasing these two around a little bit, I let the airspeed wander, as well. I thought it a little close to a three and a half, but I didn't want to give you a three and a half. It is marginal, as far as being satisfactory.

Okay, breakout and missed approach were okay. I didn't have any problems there. I was able to trim the airplane up in the climb. I put in 95 percent torque and I didn't get my 600-ft/min rate of climb at first, but at least the missed approach was controllable. I could have looked down and done some auxiliary tasks, as in a single-pilot case.

Aircraft response in pitch and roll, sensitivity and predictability, were good. I feel that the speed stability is still not very good. The airplane still tends to wander off speed and without flight-director speed control was fairly moderate compensation.

Change the pilot rating to a four. A three and a half to a four is what I want to give you for that particular one, but you can put down what you want on that. I feel that we've crossed that border there. These are minor, but annoying deficiencies that I'm talking about here as I go along.

It's the pitch axis, I think, primarily. The only reason for my having problems in tracking the azimuth, I think is just a matter of getting back into the swing here in doing my bracketing. I've been made lazy by the lateral flight director, in the past.

The collective response was okay and predictable. I didn't notice much in the way of coupling in the free run — there may have been. I think there is a little bit, but I didn't see any here. The yaw axis behaved itself okay. We only had one flight director and that was for the collective. It certainly reduced the total pilot work-load. I think without that the pilot rating would have dropped down maybe towards a six, or at least a five.

The raw data scan. I was able to do that and auxiliary tasks — right now that's the end of my comments.

Single Pilot: Missed Approach

I had a better chance to observe the speed versus, or the speed stability with sort of hands off with the attitude trimmed. It was a little bit better than maybe I had indicated on the first two-pilot commentaries. However, I did have some disturbances in attitude that were induced during the auxiliary tasks here in the cockpit, during the missed approach. However, I was able to look down and copy down the clearance and read it back, without any concern, without losing control or anything.

The main problem with this for single pilot is the lack of a pitch and roll flight director. Although we do have a pitch and roll attitude to help us here, this is a task — a fairly high demanding task, particularly with the auxiliary duties here. You can let go of the controls, you can look away, but I feel that the airplane is disturbed more than I would like to see it, if I were by myself in this thing than with passengers.

I feel that for single pilot, this is still performed adequately, and I think with a little more learning I would do better, which would improve it; however, I am going to stick to a fairly low pilot rating here — a six.

The two-pilot ratings for the missed approach, as well as the continue to land, I am going to leave the same. I am going to change them both to a five and a half.

The specific comments all remain the same; however, I want to repeat that the speed characteristics with the pitch attitude here are a little better than I thought they were at first. I was maybe not letting the pitch attitude alone once I got it trimmed. It seemed to stay on speed a little bit better this time than I had judged on the first two approaches. However, I am rating the aircraft down from a three and a half as I feel that for this particular flight-control system for single-pilot IFR, we should have the three-cue flight director available, and that's the end of my comments.

Single Pilot: Continued Approach

Again, a little surprise here. I am an advocate of attitude loops for IFR work. This one just isn't holding the helicopter the way it should as far as airspeed control is concerned. I suspect it is the attitude versus airspeed characteristics of the helicopter itself but, it is in a way a speed stability problem — it's not just the — it doesn't do very well. I will comment on that here further as I look for a pilot rating.

I am going to give it a six. I may change that as I go through my discussion here. Let's see. Okay, to describe a little bit of the problem which surfaces whether it be single- or dual-pilot. That is, the big one here, the speed control with attitude. You've got a nice attitude loop, but the helicopter for some reason or other is not very sensitive, I guess it is insensitive. The attitude versus velocity relationship on it is pretty flat.

If you make any small attitude corrections, the airspeed, sometimes, just well, let's see — if you don't attend to holding a good constant attitude, the airspeed wanders off. It seems to wander off whether you are maneuvering in pitch or not. It just seems to wander away.

Okay, intercept and tracking, again I had some problems with the lateral tracking; that is, of the azimuth. I had to do it in a raw data sense, but that was not a big problem. The glide-slope tracking was kind of poor in a couple of places. I think I went below the glide slope a couple of times and maybe above, but it wasn't very satisfactory, either. I didn't feel good about it.

The flight director, correction — the collective flight director would have helped that, but I think I got distracted trying to salvage airspeed control a couple of times. I broke my scan down and didn't really put that collective flight director to good use because of breakdown in scan.

Aircraft response — those are the same as with the other ones — the same comments on everything else down the line. I didn't make the missed approach this time. I had to really honk it up to stop it. I believe it's the airspeed versus attitude characteristic that I talked about that was the culprit; that's the end of my comments and I am ready for my second single pilot.

CONFIGURATION T22

Pilot M
Runs 176-180
Ratings: DP = 4-1/2; SPMA = 5; SPCA = 4-1/2

Dual Pilot

I think once I understood what I had as far as the augmentation and the control system, I didn't appear to have that much of a problem with that approach. I did find, although, that I — it was necessary to continually cross-check airspeed. At one point, I did have a 10-knot excursion or deviation from the 60 knots.

Again, control activity was not as bad as it has been in the past, but it did require quite a bit of control inputs, small inputs. Overall, I think I would give that one a . . . well, say that it required a moderate pilot compensation during the missed approach. Once I got everything trimmed up and was stabilized on the climb-out, it was almost a hands-off situation, even with the gusts. There would be 2- or 3-knot excursions, but the aircraft was stable and would return to that trimmed situation. Overall, I would say that that was a little more than a moderate pilot compensation. I would give it about a four and a half.

Single Pilot: Missed Approach

That approach felt very comfortable. I was able to set the localizer and the azimuth and the glidepath . . . no particular problems. Airspeed . . . I was a lot more stable on that one. The breakout, the missed approach — transitioning to the missed approach — no great difficulty, relatively easy to maintain the airspeed.

Once I had tuned the White Lake . . . and started my turn, I noticed a decreasing airspeed as I was climbing out and I made a correction. I felt I made a more than adequate correction to bring the airspeed back to the 60 knots. It was about a bar width below the horizon line, and then the next time around on the cross-check, I noticed the airspeed still decreasing. At that point, I went to what I would consider to be a significant nose-down attitude trying to bring it back, and with my consternation about that, the decreasing airspeed and getting the airspeed back, I turned to the localizer course inbound to the White Lake VOR; however, I just feel that that almost seemed to be unnatural, at that point. I don't know whether it was the attitude augmentation or what happened or if it was just me; but I did feel that I had an adequate input in to correct the deviation I was seeing. I think I would give it a five in that anything that is, again, not quite correct in the cockpit, the overall cross-check and the control activity — the requirement for very intense cross-check again occurs; but it wasn't as bad as it has been in the past. I think, taking everything into consideration, because of considerable pilot compensation — I would give it a five.

Single Pilot: Continued Approach

I think I would give this one a four and a half. There was a little more than moderate pilot compensation, but I wouldn't call it a considerable one. Again, the cross-check, the additional tasks that are required in the cockpit. It really

required a good cross-check between attitude and the airspeed indicator, as I've said on several other configurations. I do feel that I pretty well had both the localizer; the azimuth and the glidepath pretty well pegged. I did deviate by one dot at one time.

The difference in sensitivity, again, between the command bar and the actual localizer position on the raw data. If you are staring strictly at the attitude indicator command bars, it might give you the feeling that you have a much larger deviation, but once you check the azimuth and the raw data, you find that you don't.

Overall though, no great problems . . . the intensity of cross-check. I think I will give it a four and a half.

Pilot G
Runs 244-227
Ratings: DP = 3; SPMA = 4; SPCA = 4

Dual Pilot

The overall impression was a good one; certainly better than a three and a half without any further consideration. Obviously, satisfactory without improvement, in other words.

Let's see — I had a little bit of problem. The only thing I saw there was a little problem with airspeed tracking. I didn't quite have the attitude when I decelerated to 60 knots prior to intercepting the glide slope. I didn't quite have the precise attitude for 60 knots established. I had to sort that out during the approach a couple of times. Even with an attitude loop, I overcontrolled a little and it threw the glide-slope tracking off a little, but those were minor disturbances, or minor errors. Airspeed was the only thing that I had trouble with there. Everything else looked pretty well locked on, so I will give that a three.

I will have to give that a three. The pilot compensation, I think, is because of lack of a pitch flight-director it . . . the desired performance requires some minimal pilot compensation with respect to not overcontrolling pitch attitude. That's why I rated it a three.

Okay, task performance on the back here. The intercept and tracking were good except for the airspeed thing I talked about. The breakout and missed approach, also, were a piece of cake. A nice attitude, stabilized aircraft.

There's one comment that ran through my mind. While you are in a turn with this attitude control system, you can't let go of the stick with your right hand to write something down in the way of a clearance. This would be a single-pilot consideration but at least I will make the statement now. If we had a rate-command attitude hold with good force via centering, we could set the airplane into a turn and let go of the stick, and while we are in the climbing turn, we can actually sit there and write down a clearance. This is just a comment, I think, that's worth noting. We do not — we have not looked at rate-command-attitude-hold on this experiment. Maybe that should be discussed in the report.

Pitch and roll sensitivity, predictability, were good. I saw no coupling with respect to collective and the yaw axis looked alright. On the display side, the

collective and roll flight directors reduced pilot workload significantly, I think. Probably responsible for making it a three, rather than possibly a three and a half to a four.

Pitch attitude tracking to hold airspeed was the only thing requiring pilot compensation with respect to flight director. We didn't have a pitch flight director, and I expect when we do get it it is going to be a real piece of cake, almost like an automatic flight control system.

I was able to scan the raw data without any problem. The workload in flight director — in the primary scan in the flight director modes was such that I could look at the raw data and really anticipate some of the collective flight director commands — by looking at slight glide-slope errors that were building.

Auxiliary tasks don't apply, and I believe that's the end of my comments. I'm ready to set up here for . . . the problem with airspeed control again. I described this in the single-pilot; that is, the dual-pilot.

Single Pilot: Missed Approach

I would like to fly that one again. Actually, I don't . . . I think I had better fly it again before I give you a pilot rating on it.

I am glad I repeated that one, because it points out, I think, an important factor here. Definitely, this helicopter has a very flat delta U delta theta slope, as I discussed with Vic very briefly before I went in the simulator and it does cause, although it is nicely stabilized in pitch, it does cause a moderate pilot workload to stabilize on to a new airspeed, to make an airspeed change and to stabilize on it — to find the right attitude. That attitude is being on a flat slope. It takes a while to find where it is, so it is just a matter of the time and the attention required which slows down your scan and, again, if you overcontrol in pitch, you can create errors in your glide-slope tracking. This causes you to start pumping the collective and that feeds back into the airspeed control a little bit; although this is a good decoupled helicopter. That, I think, is the thing that should be identified for this particular combination of display and flight-control system; as being a potential problem. I think if a pilot got used to flying this aircraft, that is, got some experience and flew it day to day, he could cope with that fairly well.

Calling the shots as we see them here as we change configurations — that is identified as a problem.

Okay, picking up the pilot rating chart — I am going to have to cross the boundary here on the three and a half. I feel that that characteristic I just described is certainly not a three and a half or better. A pilot rating of four, I think. That looks good there. Marked down from a three and a half, giving you a four, because of the airspeed control, the characteristic of . . . I'll call it "attitude airspeed stability characteristic." Delta U, delta theta.

Other comments — the azimuth tracking, of course, with the flight director, there's no problem at all. The breakout and missed approach is good. What I do, is turn to an approximate heading, because I know where my alternate is going to be, which I think is fair. I can't let go of the stick and copy a clearance, so I turn to the approximate heading. I can let go of the stick. I have to keep watching the airspeed, though, because it does wander around a little bit. I put in the power,

of course I am climbing, and then copy the clearance, I can change frequencies and so forth. The breakout and missed approach went along okay.

Aircraft response in pitch and roll sensitivity, predictability — no further comments there. Same with the collective and the yaw characteristics. Same comments apply on the flight director. To review, again, the roll flight-director was excellent for azimuth tracking. Certainly collective flight-director was good for neutralizing or taking out the errors that were created because of lack of pitch flight director — making airspeed changes and causing problems with the glidepath tracking. I think I have talked about all of those.

Auxiliary tasks — this is a configuration that you can let go of the stick in straight and level climb and level of descent. You can't let go of it in a turn, as I have already discussed. If we had a rate-command attitude in roll, it would . . . we could do that. However, you can copy a clearance and look away, change frequencies, do the single-pilot tasks here, duties, without the aircraft losing much in the way of attitude control. However, airspeed can wander if you don't have the attitude set for the airspeed that you're trying to hold. It will wander around a little bit. That's the end of my comments.

Single Pilot: Continued Approach

This is the second single-pilot without the missed approach. I will still stick to my pilot rating of four for the same reasons. Airspeed control — I still didn't nail that airspeed down this time. A little less in the way of disturbances into glide-slope tracking, but I still did overcontrol a little bit and cause some extra glide-slope tracking workload, with respect to power. All of my other comments remain the same. That's the end of my comments.

Pilot K
Runs 258-260
Ratings: DP = 2-1/2; SPMA = 2; SPCA = 2

Dual Pilot

That was an interesting configuration. The errors in airspeed . . . down the slope, were my own fault. Once I got it down to 60, the speed control seemed real nice; no problem.

The two-cue flight director was an interesting situation. My previous comments about the fact that the collective cue was easier to get at . . . it made me tend to ignore azimuth on the HSI are no longer valid, because I had an azimuth indication on the same instrument. It made a big difference.

I found that the . . . the speed cue, the horizontal bar on the flight director . . . I didn't really miss it, because the aircraft had quite good speed control. It had extremely docile, well-mannered pitch-attitude characteristics.

Possibly, in the missed approach, it may be nice to have the speed cue on the flight director, simply because it gives you a definite attitude to pull up to, and I tended to be searching a little bit. However, overall, I found the two-pilot

airplane was certainly acceptable, certainly satisfactory. However, I would say that it certainly has some deficiencies, although unpleasant, I don't think I would like to give it a three. I would like to give it a two. Make it a two and a half.

Single Pilot: Missed Approach

That one was definitely acceptable, definitely satisfactory, without any qualification, it is satisfactory. Assuming that it is the same model that I flew in the two-pilot task, I would like to give it the same rating, a two.

The auxiliary tasks here really didn't bother me at all in the single-pilot task.

Single Pilot: Continued Approach

This was not much different than the last one, but the difference was that I felt even better about this model, because the lack of a speed cue, without doing the missed approach; the fact that I didn't do a missed approach. I really didn't notice the lack of a speed cue here — the aircraft speed holding or the attitude holding, the capabilities down the slope; all were just so nice that holding speed is really not too much of a task. Any speed excursions that were noticed on this thing were probably indicative that my workload was pretty lax. I would also give this a rating of two, although it did feel better than the last one.

CONFIGURATION T23

Pilot M
Runs 6, 7
Ratings: DP = 3; SPMA = 4; SPCA = 4

Dual Pilot

Missing.

Single Pilot: Missed Approach

Okay, the last approach was a single-pilot approach with the flight director. I had no particular problems on the innerset. With the additional workload, it did cause me, occasionally, to break my cross-check to rate the . . . or the transponder or to switch hands and write on my knee board.

The aircraft response, again, no real problem. Occasionally, I did lose 5 knots or would slightly deviate from course; but, by having the flight director I was very easily able to go back and recover the glidepath and azimuth.

No unusual collective, pitch, roll or yaw couplings that I noticed. The flight director . . . no problems there. I was again able to pretty much follow the main flight director. It did cut me down a little bit with the additional tasks of going

to the secondary instruments — airspeed and cross-checking airspeed, vertical speed, and the HSI; but, having the flight director definitely helped.

I think just from the overall increase of the pilot workload in copying the clearance and so on, I would have to give that one a four. It required moderate pilot compensation.

Single Pilot: Continued Approach

Again, no real problem. I think getting used to the cockpit layout and getting used to the transponder and frequencies, I am able to tune a lot faster than I have been in the past during some of the practice runs. No particular problem noted on that approach.

Intercept tracking — again, the same annoying problem on the deceleration from 80 knots to 60 knots. I am getting quite a needle deflection on the horizontal needle. I am finding it necessary to lead it a lot more going to airspeed and checking airspeed and rate of change of airspeed.

No unusual aircraft responses. In the display, the only problem was that particular horizontal needle. The auxiliary tasks — there was one point where I was tuning a transponder and I was pretty far off, I guess in the azimuth. Again, with the three flight directors I was able to readily get back in.

No real special problems once the breakout occurred. I felt very comfortable with it. Again, just a slight amount of increase in the workload. Well, a definite increase in the workload because of the single-pilot situation and, overall, I think I would give this one a four, in that it required moderate pilot compensation just from the motions and the requirements to divide your attention about the cockpit.

Pilot G
Runs 18-21
Ratings: DP = 3; SPMA = 6; SPCA = 4

Dual Pilot

General comments are, as I have already indicated from the free run, this is a good combination of display and control system which rates a good pilot rating. I saw nothing there that was really objectionable from handling-qualities or display mechanization point of view, as far as sensitivities and gains and compatibilities . . . felt comfortable, the workload felt comfortable with respect to an IFR approach down to minimums and a go-around.

Going through the handling-qualities rating scale here . . . go up to the satisfactory-without-improvement category, certainly. There's always some pilot compensation required. I don't know whether the word is compensation or workload in place of compensation. I always feel that the demand is on the pilot so, I always figure that if there is no demands on him at all, then it's a one but, definitely there is some demand here just in interpreting and reading instruments and scanning, which, I feel, is a pretty good workload. That is compensation.

Again, I look at the deficiencies — I did find I had to search around trying to trim the airplane. I never felt well-trimmed and, I don't know, I can't really sort out why. I used the coolie hat, I did not use the disconnect at all. I did not use the wing-leveler feature. I tried to use the coolie hat to trim the airplane and I never really felt completely settled down on my trimming. That's what I would call mild objection so, I can rate that, based on all that conversation and verbeage . . . I will give that a pilot rating of two and a half to three.

Looking back on the other side . . . specific comments other than those I have already given you. Intercept and tracking was good — no big problems there. Flight director for the collective power change was good as far as getting me on to the glide slope. The . . . lead that we have in there now certainly helps in that tracking, that power flight director.

Again, during the tracking, I was trying to settle down on a final trim. The workload was to the point now where I could really try to use some finesse in trimming and, I never quite got where I wanted to be — other than that, it was great!

The breakout and missed approach worked fine. I took my time bringing in power and then the needles; that is, the pitch and roll needles, and I was already at my climb-out speed of 60 knots so, the transition to a new speed was not required there, which made it quite easy. The go-around director, flight director, logic looked good, straightforward, and the workload in the go-around was maybe slightly greater than that during tracking but only because of the transition I had to make; so it all looked good.

Aircraft response — I think I've commented on it. Pitch and roll sensitivity and predictability, collective and yaw — all of those look good, other than the trim that I talked about. That's a relatively small item. The display — I think I've talked about number three in the displays already. Flight director sensitivities, responses, capabilities look good. I was able to look down and check my raw data scan. I did not get flight director fascination here.

Auxiliary tasks don't apply here — no special problems and, that's the end of my comments.

Single Pilot: Missed Approach

Specific comments — I will give you a general comment. The only thing that was a problem, of course, was the usual high auxiliary load point of copying a clearance and trying to execute the missed approach. With this flight control system, I decided to go ahead and roll out after I made my left turn. I guess I had gone through about close to 180° of turn, at least, on heading back towards the north and rolled out and tried to let go — to trim it out — to try to copy the clearance, and I really didn't get it trimmed very well. That kind of reflects back on my other comment earlier regarding the trimmability. There's something here that I'm not getting on to as far as being able to trim it out so I can let go of the controls even though we have an attitude system here, essentially. I did have some difficulty there and that is why I would rate this particular approach down because of that specific incident there. The airspeed really went down to 30 knots. I think the computation went bad and the thing started going around in circles.

In going down, too, I had a thousand . . . rate of descent rate on even though I had climb power so, I don't know what happened to it there. I really lost control

of it. I would probably want to fly that again to make any comments, any pilot ratings. I hesitate to rate it way down because of that one situation, but I feel it is because I didn't get a good trim, I could not let go.

Researcher: Did I understand you to say that you want to fly that one again?

Pilot: Yes, probably. Look, I am going to have to fly it again, anyway, here. This one is going to be land, isn't it, if I play it by the next approach. Let's go ahead and repeat this one.

[Repeat run]

My first remark is that the second approach was . . . went a lot more smoothly than the first, but that's because you get a little bit of practice — you know what to expect on the calm. I did make two errors in selecting frequencies; I transposed some numbers, which is an indication of an "uncool" pilot, a little high on workload.

My pilot rating is going to be better. I still had difficulty in trimming the airplane once I got it established in the go-around climb. I rolled it around to the left, put it into a climb, put on climb power about 95 percent and still had some difficulty in holding airspeed. Airspeed was kind of all over the place, which says to me that the pitch attitude might be a little on the light side; that is, the pitch-attitude loop. It deviated from where I had it trimmed initially — at least when I added power, I had a hard time retrimming. I think that was my main problem. Laterally, it looked okay.

On the first approach, which I messed up, I did lose airspeed. That's an indication of a pitch-attitude problem, possibly. On this one I got into a fairly high sideslip as I pushed on the pedal, but the indicator helped me to cope with that, at least I was able to identify it.

Okay, with all that as a preamble here — because of the inability to really let go of the controls and copy a clearance or tune a radio or whatever, I have to drop the pilot rating down to a substantial amount here, a six to a six and a half. It is about at that six and a half borderline. I think with practice this . . . I could do better but, that's rated mainly down because of the trim problem I've talked about.

The performance on the back, intercept and tracking, still look good. The big thing here as far as the workload, single pilot, the missed approach; I think I've discussed that already. Aircraft response — the aircraft responds well about trim. It's the trim itself that I feel is the problem in pitch, primarily. The flight director is doing a good job. I feel that the breakdown here is in the controllability of the aircraft. Of course, the question of consideration number four of the auxiliary tasks, high pilot cockpit duties hwere as far as changing frequencies. Any place where you have to look away from the primary instruments scan, the airplane does, for me at least today, wander off. Maybe it will improve here with some more time. No other special problems. That's the end of my comments.

Single Pilot: Continued Approach

Okay. That third IFR run. I am convinced that the trimmability is the major problem that I've run into here. Again, the handling qualities on the flight director look good but, I am constantly searching around for trim. There's something that

. . . by the way, again I repeat, I am using the coolie hat. That's the end of my comments.

Pilot K
Runs 143-145
Ratings: DP = 2-1/2; SPMA = 3-1/2; SPCA = 4

Dual Pilot

Okay, that one, I thought was fairly nice. I would have to say that it's probably minimal; it was a slight pilot compensation required. I had some fairly gross excursions on the glide slope — one and a half dots; however, that was all my doing. It was not the aircraft, at all.

It also gives me a fairly . . . case which the aircraft handled quite well. Laterally, the lateral channel, I thought was extremely good. The pilot workload was hardly noticeable laterally.

Longitudinally — quite nice. I'll have to give that a two and a half. The pilot compensation was extremely minimal, but I don't think that it wasn't a factor, there was certainly some pilot compensation required. It was quite a nice airplane.

Single Pilot: Missed Approach

Not much change — it seemed that the aircraft was pleasant enough. The auxiliary task load doesn't appear to have a great effect on the pilot workload. However, what does become noticeable is the overshoot and in to the missed approach. I would say that that part of the task, the overshoot to the missed approach, with the auxiliary tasks thrown in . . . switch in frequencies, and so on, would make this a little bit worse than the two-pilot. I have to say, though, that it takes a bit less than moderate pilot compensation. I have to give it a three and a half.

I think I have just as well said enough. It was quite a pleasant model.

Single Pilot: Continued Approach

On that one — much the same as the previous run — laterally, directionally, the aircraft was very pleasant, really. No real improvement warranted laterally or directionally.

In the longitudinal sense, it took a bit of pilot compensation to fly that. This particular time on this run, I ended up with one dot in the glide slope and that was as usual to tune in the frequency change on the VHF for the Gulf Tower. So, in this case, I pretty well have to attribute the excursion I had to dividing my attention to the auxiliary tasks, and I would have to call this one moderate compensation. I didn't get the missed approach — just the excursion I got on the glide slope with the auxiliary task. I will have to give it a four. That is the extent of my comments.

Researcher: We need your pilot rating.

Pilot: Yes, I called that one a four.

Pilot S
Runs 194-196
Ratings: DP = 3; SPMA = 5; SPCA = 5

Dual Pilot

It is somewhere between a three and a four. Some mildly unpleasant deficiencies and it takes some pilot compensation, but it certainly . . . the deficiencies are relatively minor so, I'll cop out and say it is a three to a three and a half.

I think that what we do from a certification standpoint, if we could pretty well assume that someone has got some training they should be able to do that task. It's considerably easier than say, on a one-time basis, so that's what would kind of influence my thinking — it is not a four maybe from a straight evaluation standpoint, it would come out to be a four but, it is really not all that bad from what we see in the real world, so that's why I sort of leaned towards a three.

Single Pilot: Missed Approach

Let me go through this list here. It requires considerable pilot compensation, especially with some divided attention, such as changing the transponder, the radio frequencies. On the two-pilot, the pilot doesn't have to divide his attention on this one — you could get behind the airplane if you didn't — if you weren't pretty quick and agile with your hands. So, it's a five for it requires considerable pilot compensation.

We'd approve that under what we'd call a limited approval. We have adequate training . . . we wouldn't approve the single-pilot at all, and I don't know if they could make it, make the criteria with the two-pilot configuration. It would be close, real close.

Single Pilot: Continued Approach

That particular configuration requires extensive pilot compensation, and its deficiencies warrant improvements, so I will rate that as a five.

As far as the single-pilot approach it is following a failure of some type. It is manageable and all, but as far as routine operation, not an emergency type, it definitely couldn't even be considered, I don't think.

Pilot G
Runs 231-233
Ratings: DP = 2; SPMA = 2-1/2; SPCA = 2-1/2

Dual Pilot

Okay, run 231 — the big addition here, of course, is a good, old pitch flight-director, which assisted me in getting the airspeed change. I noticed, though, I did have some trouble still with the flight director. I didn't track it close enough to

precisely run from 80 to 60 knots without an overshoot. I overshot down to 64 and then back to 60, which again, I think surfaces the delta-U-delta-theta slope. However, it reduced the workload, and I think it would be interesting to look at a couple of time histories with a pilot in the loop; one with the flight director . . . just look at the . . . I guess we could have a plot of deceleration from 80 to 60 in level flight with the various combinations; rate only, rate with flight director, attitude only, and attitude with flight director — to see what sort of overshoots in the time it takes to do that. I think that would be an interesting little plot to look at.

This one was nice and comfortable, better than a three and a half. Let's give you a two to a two and a half on that.

. . . test performance . . . they were all good right on down the line. The only thing is what I have already talked about. It still takes a little bit of time to get the new airspeed even though you have the flight director. I think with time, it would, you would probably be able to do it without an overshoot. Everything else . . . I have no other comment about. They are all good, glowing reports. I am ready for the single-pilot.

Single Pilot: Missed Approach

Okay, that's the single-pilot approach with the missed approach and that felt real comfortable. Again, there's some learning here. I saw nothing that would tend toward worse than a three and a half rating. Airspeed control was pretty good this time. The attitude system will hold the airspeed once you get to it. Of course, that good old flight director will tell you when you need to make small attitude adjustments. They were all small and, thus, there was no tendency for me to precipitate any glide-slope errors, so the collective activity was also rather low, and I was able to keep the glide-slope . . . flight director pretty well centered.

Give that also a two. Change the rating of the dual-pilot to a two, and give this one a two to a two and a half. Just indicate a little bit more cockpit duty, but this is certainly, as far as the certification aspect goes, a real good combination of flight-control system and display. So, a two on the dual-pilot and a two to a two and a half on the single-pilot.

Going through the back of the chart, here — I don't have many more comments than I've already given you on this configuration. The flight director is great. It certainly has improved the airspeed change in tracking — the whole approach. The pilot workload level, even with copying clearance, I actually wrote down and looked at. I took my hands off the controls. I took my eyes away from the instrument scan, and still the aircraft held in its trajectory the way I wanted it to.

The only comment, again, I have is the one I have made several times. Maybe a rate command attitude in hold in roll might be preferable for this "up and away" flying and executing missed approaches, copying clearances and so on. That is the end of my comments.

Single Pilot: Continued Approach

I had one little glitch there that I attributed to looking down and changing the transponder at a time when I should have been making the transition on to the glide

slope. It just occurred at the same time. I don't think it reflects the display system or the flight-control system at all. It is just a matter of not initiating a change in flightpath trajectory at the right time. So, I will keep my comments the same as for the previous run and give it the same pilot rating.

CONFIGURATION T05

Pilot G
Runs 292, 293
Ratings: DP = 4; SPMA = 4

Dual Pilot

Okay, take away those old flight directors and the tracking sure goes to pot — I'm a little spoiled by them. I was sitting there fighting the airspeed thing and then I got so concentrated on that that the glide-slope tracking got real bad. I had to make a correction back on.

When you're in here without a flight director in the pitch axis which we haven't had all morning, I still am finding I'm having problems tracking airspeed precisely, and now we've taken away two flight directors. The very obvious effect here — I never did get squared away on the azimuth and I was on the glide slope with a steady rate of descent for only a very short period of time. However, the approach was carried down and this would simulate a loss of flight director situation, which I know we are interested in. The question is, with respect to certification, is it a five or better? I will have to search my heart, here. I will give it a five. Maybe I might want to change that after I discuss a thing here.

Task performance . . . this is a combination where some practice, if we had time . . . if I could make two or three more, I think my tracking performance and my opinion would probably improve as far as that goes. I feel this is a certifiable situation with respect to an emergency where we lose part of our display, in this case.

Intercept and tracking, I've talked about. Breakout and missed approach — the same. It was a relatively ragged tracking on the gages here, but safe for an emergency situation.

Aircraft response on pitch and roll. I guess I've talked about those previously. One comment, and I'm not real sure of this, but I feel that maybe the attitude — this rate-command-attitude-hold — I just wonder if there's any history . . . when you rotate to a new attitude, does it hold it or does it drop a little bit? It is hard to tell just how precise that is. I have a feeling that maybe the attitude aspect of the pitch-rate-attitude-hold might be a little on the loose side, but I cannot say for sure. That's the only comment I have there.

Roll was okay. Collective and yaw — no displays to talk about. Raw-data scan, I had to use that. Again the comment, I think I could improve the raw-data tracking if I had more runs to make.

No auxiliary tasks. I'll stick to my pilot rating here of a five. That's the end of my comments.

Single Pilot: Missed Approach

Okay, that was very nice and, certainly, there was a learning curve there. I think I did better on this trajectory than I did on the dual-pilot one; which says a lot for the control system without flight directors whatsoever.

I think I am gaining some technique in coping with the airspeed problem, and I feel that this is a single-pilot certifiable for emergencies without flight director. In the case of flight director I feel . . . the case of lost flight director, I feel that the flight control system is sufficient for the case we looked at . . . the tasks we looked at . . . single-pilot.

What did I give you for a dual-pilot rating on this configuration?

Researcher: A five. I have got the learning problem in here — we understand — if you wish, you may revise that, we won't hold you to anything, not on the last day.

Pilot: I am just thinking — the dual and the single-pilot performance here, again, were sort of comparable. Added tasks apparently did not degrade my performance. I didn't feel that the workload went up very much with that. Let's give them both a pilot rating of four.

Comments will be the same. These are the additional ones — I purposely took my hands off the controls and looked down and spent a lot of time looking at the control heads and did a lot of writing and so on, just to saturate myself and get away from the scan and "hands-on" and yet, the helicopter pretty well behaved itself. To me that passes a single-pilot test, a basic one, and I'm rating it below a three and a half only because I feel you need the flight director, and I'm rating it below a three and a half to show that if you lose a flight director, it is still certifiable, and yet, really not too bad. So, if that sounds logical to you, that's the end of my comments.

Pilot K
Runs 299, 300
Ratings: DP = 1-1/2; SPMA = 2-1/2

Dual Pilot

No different comments, really, than my comments for the previous approach. The two-cue flight director. I really didn't find I lacked any information, any problems without a flight director. I will give this one, also, a one and a half, it is every bit as good.

Single Pilot: Missed Approach

That was definitely acceptable, definitely satisfactory, and it is satisfactory without improvement. The deficiencies, again, I thought . . . well, I'm sort of split between negligible deficiencies or mildly unpleasant deficiencies. So, again, I will give this one a two and a half.

A good portion of that, also, was "hands-off" flying. The excursions in speed and so forth are not indicative of my workload at all.

CONFIGURATION T07

Pilot G
Runs 290, 291
Ratings: DP = 3; SPMA = 3

Dual Pilot

Okay, I have a question. First, Vic, review on this particular configuration with rate-command-attitude-hold, is there input decoupling? Does it apply here? Are you depending on the attitude loop to decouple or what?

Researcher: There is some input decoupling in addition to attitude loops.

Pilot: It is peculiar. It is good that I ran these two configurations today. I actually had an easier time holding airspeed during the approach; that is, tracking the MLS, than with the rate command system, than I did with the attitude-command system. So, there is something peculiar about this. The apparent delta-U-delta-theta is better with the rate system. That's all I can say; that's why I made a second run, just to verify that. It . . . there's something there, I can't put my finger on it; all I can do is just make an observation.

The missed approach is very nice. I am already anticipating a good rating. For the last configuration the two ratings were, the single and dual ratings, they were spread apart — a large delta pilot-rating. I would anticipate this one to have a very small spread.

Now I've got to get you a pilot rating. The only thing I saw here was a minor degree or level of workload required to hold airspeed precisely. You've got a nice attitude system here, so the tendency is to go ahead and use it by just putting in small pitch-attitude changes just to correct a small airspeed error and let go and just wait and see.

I noticed that airspeed kind of wandering around a little bit. Again, I saw some coupling into the vertical axis. On the first approach I made of these two, I was thinking about handling qualities and not settling down on my collective tracking task. I would like to throw that one out as far as any — that first one, that is — as far as any performance data is concerned, because it is a qualified run.

I think if we compare this approach with the previous configuration, I think my tracking is better down to the missed approach, but maybe not.

Now for the pilot rating. I will give it a three. I am rating it down from a one because of the time and attention required; even though we have an attitude system, the time and attention required to nail down — to get settled down on airspeed and the disturbance created in the collective tracking task or glide slope, the disturbances created while trying to make pitch changes to settle down on the airspeed tracking task — a pilot rating of three.

I think I have covered most of the stuff on the back here. The intercept in the tracking. The breakout and missed approach were nice. On the missed approach, it is more or less just holding a nice climbing trajectory with a rate-command-attitude-hold

system — as I have said in the past, that's ideal for that. I brought that task down to a really comfortable pilot workload level.

Pitch and roll sensitivity and predictability all look good. The only unpredictable thing in pitch would be this airspeed thing — maybe none of the other pilots are having this problem, but I certainly see it.

Roll is great! Just real great! Makes for nice lateral tracking. Collective — the only problem there I see is that I am having to use a little bit more collective activity to control the glide-slope errors that I am putting in when pitching the airplane around to control airspeed.

The flight directors are good, sensitivities are good, raw data scan — no problem there.

Single Pilot: Missed Approach

Run 291 — as predicted, I feel that the pilot workload for the dual-pilot one here was just about the same — for the single-pilot, about the same as dual. I was able to pass the test. I could look away and take my hands and feet off the controls once I had a new trim in. The helicopter would stay in its desired trajectory during the missed approach without any problem.

The only thing I saw was some airspeed control problem as on the dual-pilot so that stays the same. The effect of added workload due to auxiliary tasks really does not degrade the pilot rating because of the extra workload in the cockpit that is involved with that.

Pilot rating — I will give that a pilot rating of three. Did I give the dual-pilot a rating of three also? It will stay the same then, and here is why:

I think I have pretty much covered it. Again, the intercept and tracking — a little bit of problem with airspeed and glide-slope control, as on the dual-pilot discussion. The breakout and missed approach — the same. The missed approach clearance and extra workload associated with switching frequencies; I was able to cope with that quite well because of the good control system.

The aircraft response — the comments remain the same. The flight director comments remain the same. The roll control is no problem; however, we do have some glide-slope errors involved and the collective director does a good job in bringing those back in for you.

I have already discussed the effects of auxiliary tasks and that is the end of my comments.

Pilot K
Runs 297, 298
Ratings: DP = 1-1/2; SPMA = 2-1/2

Dual Pilot

I think I recall talling Vic yesterday that I never give any airplane a number one. I won't give this one a number one either. It is going to be a one and a half. Any speed excursion that we had was simply because I was flying the thing and going "hands-off," and just absolutely relaxing and letting the aircraft fly, making small, temporary corrections. The aircraft would correct back. Extremely stable in pitch, roll, no problems with the directional channel, either.

I would have to say that, probably, it is a one and a half. Damned near excellent.

Single Pilot: Missed Approach

Again, on that one, I did a bit of hands-off flying, while I was doing my auxiliary tasks, so any excursions would probably be during the hands-off phase.

I got into a little bit of a wobble on the missed approach and the speed let down quite a bit. That probably was because I wasn't paying too much attention.

This aircraft is, again, certainly acceptable and certainly satisfactory. I would have to give it a single-pilot of two and a half.

Pilot M
Runs 305, 306
Ratings: DP = 3-1/2; SPMA = 5

Dual Pilot

Okay, I would like to split the axes on this one. I think that this particular flight-control system and the information that I have available was excellent as far as the lateral control task was concerned. I was able to very accurately intercept the azimuth and had plenty of time to cross-check raw data and other things. I really felt that I was on top of the lateral task.

The pitch task, longitudinal task; something was missing again. I just feel the sensitivity of the aircraft itself, the small changes in attitude, which resulted in larger changes in airspeed caused me to really have to concentrate on the pitch attitude. As a result, I did have some relatively large excursions on airspeed. A half a dot off on the attitude indicator would cause me to lose 10 knots. So, I think, just from the concentration, the requirement to constantly trim or constantly change the pitch attitude in order to adjust the airspeed, which again resulted in a little in place on the vertical task workload; let's call that one a four. No, let's back off on that one and call it a three and a half, because the lateral task was, I would say, excellent. Let's call it a three and a half.

Single Pilot: Missed Approach

I would give that one a five, Ray. Considerable pilot compensation required just from the workload in the pitch axis. No real problem with the lateral. I felt I was relatively accurate. I was right on the azimuth. Had time to cross-check to data. I had as much as a 20-knot excursion; that is, deviation in airspeed caused by just lack of attention on the precise pitch attitude when I was changing the transponder at one time. I increased from 60 to 80 knots, and I went as low as 50 knots. However, the task of tracking the . . . both the glidepath and the longitudinal, excuse me, the localizer . . . I felt was relatively accurate, but from a workload standpoint, I would give that a five.

CONFIGURATION T08

Pilot M
Runs 307, 308
Ratings: DP = 3; SPMA = 3-1/2

Dual Pilot

Okay, I think I would give that a solid three. I was able to use the flight director again, and that really gave me an indication of trends. Any deviations from the trimmed condition I could easily note starting to develop just from the motion at the center of the flight directors and I could make an input in the right direction, and very rapidly, before the aircraft, or before the airspeed had a chance to move off the trim airspeed. I think I was within 1 or 2 knots on the whole approach. I never really had any problem. It did take a bit of concentration clearly on the flight director system; however, I don't think that it was an extreme amount so, therefore, I would give it a three.

Single Pilot: Missed Approach

Comments missing.

CONFIGURATION T25

Pilot M
Runs 79-81
Ratings: DP = 5; SPMA = 4; SPCA = 4

Dual Pilot

I would, overall, give that run or that system and workload, from my standpoint, a five. It required considerable pilot compensation. I really . . . if that had been a real approach, I should have made a go-around earlier, because I flew right through the glidepath. Again, it could have been the factor that I had just transitioned from the full flight director down to the raw data, and I was in the process of decelerating from 80 knots to 60 knots; therefore, my division of attention was

more on the attitude indicator, airspeed indicator, and I let the glidepath get away from me. I went to a full-needle deflection on the glidepath down, so theoretically I should have made a go-around at that point.

I think from just the information that I am receiving, having to decelerate at the point when the glidepath . . . glide-slope needle becomes alive, you are almost combining tasks. You are decelerating at the point when it's about time to begin descending. I find that the workload and the cross-check really gets awfully busy at that point. Overall, I would say that it required considerable pilot compensation, even in the dual-pilot mode because of the large number of different places that you have to look in order to cross-check, and the intensity of it . . . the cross-check required . . . overall, a five.

Researcher: Is it possible that we didn't make it clear in the briefing that you could decelerate, and that it's preferable if you decelerate as you're going down initially?

Pilot: No, that wasn't clear to me.

Researcher: It was intended that you be at a steady airspeed of 60 at about the time the glide slope becomes active and then encounter the outer marker.

Single Pilot: Missed Approach

I think the biggest factor in that was the fact that I slowed down to 60 knots well before the outer marker was established and stabilized. I really had no problem capturing the glidepath and maintaining the glidepath. It could have been a learning curve that made it different than the previous one, but overall I would give this one a four. I seemed to have just a little bit of a problem. I was putting in quite a large correction in order to maintain or to acquire and maintain the azimuth. I overshot several times and I found that that was the axis that gave me the biggest problem. Airspeed . . . as I say, once I was established there was no adverse coupling or anything that caused me to get very far off of airspeed, but I think from the lateral axis it would be a moderate pilot compensation required and give it a four. Even the missed approach was relatively straightforward. It was a matter of establishing myself on the climb, and I found that with the airspeed-hold system, I was able — once I was able to establish it — the rate of climb as evidenced on the vertical speed indicator, it was almost a hands-off operation with a constant torque setting. I was able just to establish about a 750 ft/min rate of climb, airspeed was held, and I could copy the clearance and do whatever I needed to do. Overall, I would just say moderate pilot compensation and give that a four.

Single Pilot: Continued Approach

No real problem with that one. I think that there appeared to be a wind shear, about 500 ft or thereabouts that caused me to have a little bit of activity in the lateral axis. Again, decelerating to 60 knots gave me a stabilized situation before I went to . . . or to approach the glidepath, so my descent felt a lot more comfortable. The only thing that got away from me was switching frequencies, but I got the subtle hint from . . . box, and caught that hint right away. Overall I think I would give this one a four; mainly because of the lateral axis. However, I think that the airspeed, again, I would like to compliment the airspeed-hold system, because it is almost like an autopilot for me, once I am stabilized and set up and I can really

expand my cross-check and look at other things. So, overall a four for that with moderate pilot compensation.

Pilot G
Runs 90, 91
Ratings: DP = 4; SPMA = 5

Dual Pilot

There's one thing that influences this rating, and that is, I still don't have fixed in my mind approximate power settings for descent and climb. I should have by now, but I don't. The flight director certainly helped me to do this; that is, the collective flight director helped me to do this on the previous runs. So, the workload is a little bit higher here in trying to track the glide slope — a little bit of hunting around. Of course, the velocity held quite well. There's an increase in workload and a little bit of chasing here that I want to indicate. Certainly it's better than a six and a half; however, I think we've crossed the line here and we are down into the four-to-six category area. I've got to find out just where I want to settle in. I was able to devote, of course, full attention to the flight-control task, but with the attitude loops you can let go of things as long as you're on and look back and you're still on.

Let's see here — I will give that a pilot rating of four, primarily, due to glide-slope control. A little bit of hunting around with the power. The velocity takes care of itself. I'm trying to teach myself not to use the stick at all in pitch, just to use it laterally. That's the best thing to do with this flight-control system — just don't try to do anything with it in pitch, just let the speed loop take care of it. One tends to want to pump the stick a little bit, at least I did.

Intercept and tracking were okay. Glide slope was the one that caused the higher workload. The missed approach was real neat. There's no glide slope to track there, so just put in power. Wings are held level, pitch attitude is held and it makes a very pleasant missed-approach initiation and transition.

Pitch and roll sensitivity . . . predictability were fine. Okay, collective, I didn't notice any coupling, but again, hunting around for power settings to make the glide slope do what I want it to do. Yaw is no problem. No flight director at all. Had to use raw data scan. No auxiliary tasks and that's all my comments.

Single Pilot: Missed Approach

I think the same comments would go for the hover approach — the nonmissed approach that we have here. Okay, a couple of times there in the missed approach, in particular, the bank angle got a little bit greater than I wanted it to be. There was some added workload associated with the auxiliary tasks, which I think degraded my performance somewhat.

Let's see here. It's better than a six and a half. I'll give that a pilot rating of five, which would indicate an increased pilot workload associated with the auxiliary tasks, and my comments concerning the handling qualities of the aircraft and the flight director which, of course, is nonexistent here, remain the same.

Pilot M
Runs 97-99
Ratings: DP = 4-1/2; SPMA = 5; SPCA = 4-1/2

Dual Pilot

Overall I am going to call this one about a four and a half. Between moderate and considerable pilot compensation. The velocity hold was excellent. The wing-leveler helped me quite a bit, but not as noticeably as the velocity hold. I was able to relatively . . . to just establish an airspeed and, in general, I just kept that in my cross-check, but not quite as intense as I had before.

The problem appeared to be the localizer in establishing myself on the localizer. I was making some rather large heading inputs and changes, and again I never felt as though I had even come close to establishing myself on a constant heading that would maintain me on the localizer. I turned through it three or four times and about the last hundred feet or two hundred feet before the decision height, I got a full-scale deflection which again would have called for a go-around or a missed approach at that point.

The workload, especially in the lateral axis, on that one was obvious; although I did feel that I had complete control of the aircraft. I really felt that I was chasing the localizer needle more than anything else and, therefore, that required between moderate and considerable pilot compensation. About a four and a half on the rating scale.

Single Pilot: Missed Approach

Overall I would give this one a five. It requires considerable pilot compensation. One thing I seemed to notice on this particular approach was that the attitude-hold system appeared to be giving me some difficulty in maintaining . . . airspeed hold system, that is; seemed to be giving me difficulty in maintaining a constant vertical speed. It required quite a bit of collective activity based on the changes, the apparent changes in the aircraft attitude that seemed to be the velocity-hold system working. Again, it just increased the control activity. It seemed to . . . but, I really didn't have to worry about airspeed. I was able to make the change, the deceleration, 60 knots, and essentially not worry about airspeed — that seemed to translate, as I say, into my glidepath and maintenance of the glidepath through the vertical speed.

Again, I had quite a bit of trouble with the lateral or the azimuth. It required several relatively large heading changes in order to maintain my azimuth position. I really wasn't able to, again, peg down — there seemed to be quite a large wind shear passing between 500 and 400 ft. As I am getting very close to the tower, it is requiring about a 20° or 25° angle change.

Overall I would just say that with the additional tasks, the cross-check required, and the control activity, I would call it considerable pilot compensation but, again, I was able to adequately perform the tasks so, therefore, I would call it a five.

Single Pilot: Continued Approach

I think that one also is a five; let's drop that to a four and a half, I think the learning curve was coming into effect there. I was making more of a standard large cut at the heading indicator so, therefore, it helped with my localizer workload. The workload for that particular run . . . I think that was the reason for dropping it. I still notice the activity on the vertical speed caused by the velocity-hold system whenever I would get a slight deviation in attitude. My vertical speed would climb or descend considerably and, therefore, I was almost constantly making power changes on my way down.

The additional tasks in the cockpit — no real problem. I do really feel that the learning curve for this particular approach was a definite factor in this one, but even so, I would say it was between moderate and considerable pilot compensation — let's call it a four and a half.

Pilot K
Runs 266-268
Ratings: DP = 2; SPMA = 2-1/2; SPCA = 2

Dual Pilot

The gross excursions along the glide slope and all were all my fault. I was fooling with it, and also having a feel for how this hold works in the final stages. I finally did settle it in and it worked really great. Any glide-slope errors I had were simply because I was sitting here very relaxes and, in fact, being very, very lazy. Probably, the most amazing part of it was the missed approach. Really, all I did on themissed approach was increase the torque to 95 percent and took my hands off — and off it went merrily on a straight-ahead overshoot, with the speed hold right on the 60 knots.

That's absolutely, definitely, satisfactory for a two-pilot IFR. Offhand, though, now — I would have to give it a two. I would give it a one, probably, if I got practicing it and I got to use it more.

Single Pilot: Missed Approach

That one is certainly acceptable, certainly satisfactory. I found that auxiliary tasks . . . the only real criticism I might have on that is that it might take a little bit of time to get used to implementation of this velocity-hold thing. However, auxiliary tasks really don't enter into it, because this aircraft is set up with the velocity hold. If it is recently in trim with collective — with the lateral directional model and the velocity hold, it is really a "hands-off" aircraft. For a good portion, down the glide slope, it can be hands-off and just collective only. Flying the collective and making the odd corrections in bank angle just to track the localizer that . . . really a low workload situation.

The overshoot to missed approach — I thought it was extremely nice. About all that's required is a straight-ahead climb, an increase in collective to maximal, and just take the "hands off" — a nice airplane! I would have to say that even with the single-pilot task, it shouldn't really detract from the two-pilot, because in a lot

of cases you can easily take your hands off. I would have to give it a number two — make it a two and a half; just a touch worse.

One little thing on that that certainly doesn't reflect on the rating. It is a little startling on breakout and when you go visual and you want to change speed. You have a big speed change to make and you hit the SCAS button and hold it — I presume you are losing your pitch — your roll attitude hold at that stage and losing your directional . . . at that time, are you?

Researcher: No, you're not, although you should be losing the roll hold — with turns — we didn't have it programmed, though; but, it always feels that way, doesn't it? I think it is because you have to make . . . it feels as though the airplane is a lot looser. All you lose is the velocity loop, so it is like the attitude command system.

Single Pilot: Continued Approach

I don't have an awful lot to say that I haven't said for the previous runs. I would still — for single-pilot — well I think I would make this one a little better. I will give this single-pilot IFR a two, because really, pilot compensation was not a factor. It is certainly great to be able to take your hands off while you do the auxiliary tasks. The use of a system like that would take practice, because, for example, what happened on that first approach . . . I ended up doing the speed change while I was asked to do a frequency change. On the second approach, I delayed my frequency change until I had completed my speed change. I think it would take that amount of learning in using the velocity hold. That will certainly make it a nice machine.

Pilot S
Runs 220, 221
Ratings: DP = 4; SPMA = 5-1/2

Dual Pilot

That one is when I messed up. What I did was I didn't decelerate until I was on the marker. A lot of things were happening so, I got behind. The performance . . . it would come in somewhere around a four.

The tracking tasks wouldn't look too good there because, instead of decelerating, I waited until I got to the marker and then I ballooned, and then I chased some things. As far as configuration, with that airspeed hold feature, it sure makes it much easier. I guess the glide slope does help for . . . I mean the flight director does help . . . so, staying ahead of where your corrections should be for the glide slope. As far as the handling qualities, they are really not all that bad.

Single Pilot: Missed Approach

It is a five, a five and a half, because I got behind on the tasks; yes, I was chasing. It requires quite a bit of cockpit activity and an awful lot of attention, especially, to the course — course corrections and localizer corrections with the cockpit duties. I would say a five and a half.

CONFIGURATION T26

Pilot G
Runs 87-89
Ratings: DP = 3; SPMA = 3; SPCA = 3

Dual Pilot

Okay, interesting here, a good indication here of what trade-offs can do. Most of the problems I've seen thus far have been in pitch control; that is, power and pitch attitude to track the glide slope and the altitudes. We've looked at combinations with and without flight directors . . . with this speed hold to give us a good flight-control system in the pitch axis. With a power flight director to help us with the power . . . the tracking and the altitude speed control was good and, of course, the lateral control. I had no flight director here. I did have a wings leveler, but the . . . I was a little loose on tracking the azimuth, not very far off, but I wasn't nailed right on. So, I did the abvious thing and got a little lazy and had been used to a bank-angle steering, which we don't have now. It really showed up in the raw data scan here — I went all the way down, I think with the thing displaced slightly to the left.

The pilot workload, however, involved was relatively low. I've gotten so used to three-cue flight director that I really miss the other two needles. The speed hold takes care of that function as far as pitch-attitude control is concerned.

Now to find a pilot rating for that. I was able to concentrate my scan because I am dual pilot here. I think I will give it a three. Give that a pilot rating of three — rated down from better than a three because of, I think, crosswinds — more severe crosswinds or anything that's going to blow us sideways — it's going to have a fairly detrimental effect here, where a flight director could really help. So, rating it down to a three because of workload associated with the lateral tracking task.

Specifically, on the back of the sheet here, intercept and tracking were no problems, except for the azimuth . . . no big problems. Sideslip was never a problem, so I never got into any big tracking problems. The breakout and the missed approach was a straight-ahead climb. Again, the speed hold did a good job there and helped me maintain my 60-knot climb. The wing leveler helped me hold the straight ahead headings . . . no big problems there.

Aircraft responses, pitch and roll sensitivity, predictability, no special comment — they were okay. Collective . . . I didn't see sellective coupling. I think that has been removed. The collective tracking task, by the way, was not a consuming one. It certainly did keep me on the glide slope well without an undue amount of pilot workload. No comment on the yaw axis — it looks okay.

The sensitivity of the flight director or power flight director was okay — no special comment on that. The response was good. I was able to, in fact, had to scan the raw data and there was plenty of time for that being that I am a dual pilot here.

Auxiliary tasks don't apply. I have no special comments so, that's the end of my commentary.

Single Pilot: Missed Approach

First of all, a question. It seems to me the go-around, on the go-around flight director, you still don't have any guidance information as far as heading is concerned, huh? We have a straight, left, and right switch on there that doesn't do anything in this case, is that correct?

Researcher: That's correct.

Pilot: Okay, that approach went along pretty nicely and it sure . . . what saved the whole thing, I think, is the pitch-attitude loop that closes about velocity. It works very neatly, very nicely. Of course, both pitch and roll attitude loops . . . they are combined and after a while, one gets used to not having a pitch and roll flight director to use. It makes tracking of the raw data information quite reasonable, with a reasonable amount of pilot workload.

I didn't see anything there that got me into trouble looking away from my instrument scan. I was able to reach over and perform auxiliary duties here, tasks, and I would look back and sure enough, the airplane was still right side up. The pilot rating is not really going to change. This is one of those cases where it is not going to change much.

I can't see any reason why I would want to rate it below a three and a half. I'll tell you what I'll do, I am going to rate this one a three. There's more workload involved, but it really isn't significant to degrade the combination here of display and flight control system.

The extra one fourth there to show that it's maybe a little bit more workload, but not a significant amount. Okay, down the other side of the sheet here:

Same comments apply — the speed-hold really saves the day, as I mentioned before. The lateral loop, that is, the roll attitude keeps the helicopter right side up in that direction and it's just a matter of . . . once you are trimmed and with the decoupling in there with power, you can pull in the collective and the airplane just starts climbing very smoothly. You can reach down and take a clearance, write it down, change frequencies without any problems. So this is a good single-pilot airplane. Further comments — in intercept and tracking, in the breakout and missed approach, those remain the same for the dual pilot. Everything else down the line does. The auxiliary tasks, I think I've already talked about. The influence of those do not seem to degrade the performance of the maneuver hardly at all just from what I can see in here. I have no other special problems, so that's the end of my comments.

I hoisted the nose up because I was coming up on it pretty fast and then I remembered, "Hey, I've got to press the SCAS button," and it gave that big jolt into the system.

Single Pilot: Continued Approach

I had one point along this approach where I kind of lost it a little bit on the glide slope I was intercepting. I think I was daydreaming a little and not working hard enough, so I am going to kind of ignore that. You just might note that we probably have to repeat this run if you want a representative record of what I could do trajectory-wise.

I am probably getting a little tired and . . . the same comments go . . . and, I want to give you the same rating as before, and let it go at that.

A three to a three and a half.

Pilot S
Runs 222, 223
Ratings: DP = 5; SPMA = 5-1/2

Dual Pilot

All right — I was pretty busy. I was getting behind because, mostly, I wasn't paying that much attention to the collective director at first — I got behind it. The single-pilot version, I would say was a six. Tolerable deficiencies. Let's make it a five, moderately objectionable because if you use the flight director, the collective cue right, that will make it that much better.

Single Pilot: Missed Approach

I thought that was going reasonably well until the end. I was a little bit slow in correcting some of the tracking tasks, but I missed the azimuth by quite a bit at the very end where it is most important. I guess I was just getting pretty busy down there with the additional single-pilot calls. It is getting around a five and a half; it is considerable pilot compensation. It is not excessive, but it is extensive — so, a five and a half, to split the difference.

CONFIGURATION T27

Pilot G
Runs 228-230
Ratings: DP = 3; SPMA = 3; SPCA = 3

Dual Pilot

The biggest thing I saw there was worth mentioning. It was good and bad news. The good news being with the speed-hold feature. It reduces the pilot workload for velocity holding, significantly. The bad news is you still have the delta-U-delta-theta characteristic, which requires some work; that is, requires the pilot to still have to search for that new attitude to nail the airspeed. It still takes time, but once the airspeed is established, it holds it very, very well. With relation to that, it also appears that there is some coupling effect coming in with power, because as I pulled or moved the collective, especially for the climb, I had to put a little bit of lateral trim in. I think I mentioned this before. This sounds familiar for this configuration. It is not completely decoupled. I think, in roll and maybe a little in pitch. Another comment before I give you a pilot rating is that it was quite obvious this time that rate-command-attitude-hold in roll would be preferable for a turning maneuver requiring any more than, I'd say, a 20° or 30° change in heading, as represented in our missed-approach procedure here. I was having to hold a fairly high lateral stick force to keep that turn rate going on the go-around flight director.

I was disturbing the airplane a little bit in pitch. The airspeed controls did get away a little bit, but we have the automatic airspeed hold in . . . I must have been putting in some inadvertent pitch-attitude change, and it caused the airspeed error to build up a little bit. I am not sure whether it was caused by collective input or my pushing on the stick — one of the two. Certainly the airspeed control in the go-around was not as good as I had expected.

Now, with all of that, I still think this is a three and a half or better airplane. I will rate it a three, a straight three, because you can fly — once you are established on the glide slope, for instance — you can take your hands off of it and let it fly itself. It is quite nice. I will give you a pilot rating of three, and then I'll turn the thing over here.

Rate it a three and anything down — that is, and down from anything better than a three because of the time required to establish airspeed with the new attitude. Secondly, for some loss — excuse me, some airspeed error that built up during the missed approach and a little bit of coupling problem — those are the three main reasons.

Intercept and tracking were good and precise. The breakout and missed-approach maneuver accomplished with a comfortable workload level. Pitch and roll sensitivity and predictability were good. The only thing I have to say about . . . in the pitch, again, is the delta-U-delta-theta aspect.

In collective . . . it looks like a little bit of coupling is coming in . . . I described that. Yaw axis behaved itself. Some small sideslip tendencies, I think, due to a heavy foot on the pedal. Flight director — same comments. Sensitivity, response, those looked good. I am looking forward to a pitch flight director some day.

Auxiliary tasks don't apply, and I am ready for a single-pilot. Let me get my cockpit set up.

Single Pilot: Missed Approach

There is some learning curve effect here as I fly this configuration; a combination of flight-control system and display system. I think I do better. I was able to cope with the single-pilot high-workload tasks and still fly the airplane. I probably did a little bit better job than in my first duel-pilot flight earlier in the period here.

That system looks good and is well worth a three and a half or better. Airspeed control is, of course, good once you get it on; even during the missed approach I was able to look away and copy clearances, hands-off controls and eyes-off the instrument scan. I think that's really the key of certification for single pilot; if you are able to do both and still maintain the trajectory control of the aircraft that's desirable in a safe way; that, to me, is a major determining factor as far as the display and flight-control system trade-off is concerned.

Can a single-pilot look away from the display? Can he take his hands off the controls and perform other cockpit duties and still be satisfied with the way the helicopter is performing as far as ATC procedures are concerned? I was able to do that here.

The only small thing, again, is being able to trim to the new airspeed. I think with familiarity, one can do that better and better as time goes by.

Pilot compensation is still a factor here. I feel I must still give this a pilot rating of three, even though the workload with the auxiliary tasks was higher — the pilot rating will stay the same. Again, some explanation for that would be because of the learning curve effect. My comments remain unchanged from the previous ones, and that's the end of my pilot narrative here — I'm ready for the next one, or do I get out? I don't think I'll have time to go through a complete set on the next one. We have to look at the flight director, don't we?

Single Pilot: Continued Approach

Okay 229 — all right, the workload for that approach was better than a three and a half. The only comment other than those I've made on . . . the important ones . . . other than I've made on the dual-pilot run . . . what was it? . . . this SCAS button thing. I don't know, I would just as soon, if it is going to kick the airplane up like that, if you forget to hit it, I would just as soon not have it. I realize that we can probably get around that, but I would just as soon pull the . . . be able to hoist the airplane back and then retrim the force out, rather than have it kick like that when you punch the button. I realize it is a mechanization thing that can be overcome, but a little annoying from a pilot-operating standpoint to have to keep pushing that thing in the landing pattern.

Okay, that's an incidental thing, really. I think the pilot workload level was just about the same as on the dual-pilot approach, because the missed-approach procedure was not included. I felt comfortable. I still had the same problem with airspeed tracking — trying to get to the new airspeed rapidly. I had to hunt around for it, and once I got it, it held very nicely.

I noticed a little bit of retrim required when the collective was changed, which indicates some collective coupling, again, in roll.

I give this one a pilot rating of a three. Intercept and tracking were good except for the airspeed thing I've mentioned. I did not do the missed approach. Aircraft response — the only additional thing I can give you is my comment on the SCAS release scheme.

The flight director and displays — same comments as on the dual-pilot run. Auxiliary tasks were fairly minimal in this particular case, but did not seem to . . . I was able to do those without a significant amount of extra workload here in the cockpit. It did not distract from my tracking task to the point where trajectory control was lost, so that's the end of my pilot comments.

Pilot M
Runs 283, 284
Ratings: DP = 4; SPMA = 4

Dual Pilot

I would have to give that one a four. There was moderate pilot compensation. The velocity hold is very effective, but I did notice one thing, and that was that

that any attitude deviation with the attitude-hold system returning the airspeed back to the baseline or the 60 knots caused quite a moderate workload, I would say, in the collective axis. The sensitivity in the collective tab — command tab, was such that it was almost constantly requiring collective inputs. No real problem on the lateral axis. I was able to use the command bar very effectively, intercept the azimuth, and track it all the way down. I was very pleased with the approach but, I think, from a collective axis, the apparent feedback that you are getting between the attitude changes, vertical speed, and the command bar — the sensitivity of them would cause moderate pilot compensation, and I would give it a four.

Single Pilot: Missed Approach

I think I would give that system a four, also. I really didn't find that the additional tasks broke up the cross-check. I could make it at about the same speed that I made the dual-pilot. No problem with either copying clearances or transponder or changing frequencies.

I was satisfied with the approach — satisfied with the missed approach. The only problem I found was the large deviations, again, in the collective tab, and it just required a moderate pilot compensation as far as collective inputs. Call it a four.

CONFIGURATION T28

Pilot G
Runs 71-73
Ratings: DP = 2; SPMA = 2-1/2; SPCA = 2-1/2

Dual Pilot

First of all, I recognize a couple of things that I have talked about before with this configuration to this scheme. First, the addition of this speed-hold changes the power settings that we have been establishing here for descent and climb and so on; it is an advantage in flying instruments to know what your approximate power setting is to help you establish it and minimize your tracking error when you are intercepting. For instance, the glide slope. Here there is quite a change in descent and climb performance with a given power setting. So that kind of affects or takes away from the desirability of this configuration. It is something that can be worked out later, but that's a factor. Second, I had a surprisingly high amount of tracking problem with glide slope. The pitch attitude was being held very nicely with the pitch and speed control system, but I kind of chased the power flight director around quite a bit. Part of that is due to the thing I just mentioned, not knowing where the nominal power setting should be. I was chasing that power director and I was oscillating down the glide slope. I think your records will show that and that's kind of not so good. I feel this system has good potential for above a three and a half, yet the workload is a little high on the glide-slope tracking. It is low on the localizer and it is very low on airspeed. It is a shame that it has to be fairly high on the glide-slope power aspect of it.

Okay, those are my preliminary comments which influence my selection of the pilot rating here — I am going to have to rate this one a four because of that. Maybe when

I make my single-pilot rating runs here, I'll change my mind on this one, but right now I am going to rate it a four because of the power flight-director workload, which I feel this should probably be a two or a two and a half system. Let me rethink this thing.

Yes, I am going to change my mind here — I will give it a three, considering the . . . no, I have got to go back to a four, because going back to this decision here about "satisfactory without improvement"; I feel that that should be improved — the collective flight director. I will go back to my original statement. I may want to change my mind after I look at the single pilot. I will give it a four and then on to specific comments.

Intercept and tracking — the only problem I really had was with power. The breakout or missed approach, I talked about that. The power setting — the rate of climb that I get for 95 percent torque is lower than with the airplane without the speed control in it. That's just a comment. It didn't enter into the handling qualities, really.

Pitch and roll sensitivity and predictability are good. Pitch and roll axes all look good. Collective — I've talked about. A little bit of problem in following the flight director. Yaw is okay. Again on the displays, I talked about the flight director. The only comment, again, on the power. I was able to scan the raw data without any problems at all. Overall workload is quite low and no auxiliary tasks on this one. That's the end of my comments, unless you have questions.

Single Pilot: Missed Approach

I had very little, if any, trouble with that. I think I will change my dual-pilot rating as I said I might, based on more practice and based, also, on my experience with the single pilot. Certainly I was able to let go of the controls — trim the airplane, let go of the controls with ease and with confidence, change frequencies, and so forth, without interruption of the desired track and trajectory, attitude. It looked quite good. I think I will change the single, the dual-pilot rating. You won't let me give you any halves?

Researcher: No, you can give halves.

Pilot: Okay, stay off of those borderlines — borderline cases. All right, I an going to give . . . this may not sound right, but the . . . I know how to work it. I am going to give you a two with the dual pilot and a two and a half for the single pilot.

Researcher: Okay, let me copy that. You're giving us a two and a half for the approach you just completed and a two for the one before that, correct?

Pilot: That is correct. That change in my mind on the other one is based on reexamining power command on the flight directory here on this next approach. I guess it just took me a little while to change my gains. That all looked real good. I felt nowhere near — working anywhere near the limit on the single-pilot approach. So, it is a good combination of flight-control system and flight director that we have here; specifically, the intercept and the tracking, as well as the missed approach, were all done with ease and confidence, as I have said. I was able to let go of the controls and change frequencies and perform cockpit auxiliary tasks without concern of losing attitude nor have anything upset, which was great!

Aircraft response in pitch, roll, yaw, collective — the whole thing was good, it was excellent! The displays were . . . well . . . they were compatible; the sensitivities were good on them. The responses were good and predictable. I was able to monitor raw data and do auxiliary tasks as well. So, I am saying all good things about that, and that is the end of my comments.

Single Pilot: Continued Approach

Well, glowing reports here. I will give this one, also, a two and a half. I still had some . . . the only thing I had to do, really, was keep the power flight-director centered and it just moved around a little bit. The localizer . . . excuse me, the azimuth . . . and the airspeed were nailed. The airplane handled quite well and I just had to make some very minor adjustments on the collective to keep the flight director centered. It did a jood job of keeping me on the localizer. I don't think there is any need to say much more beyond that except that this is, so far, the best I've seen. Good work, men, and that's the end of my comments.

Pilot M
Runs 75-78
Ratings: DP = 3; SPMA = 4; SPCA = 4

Dual Pilot

I think I would give that one a three, in that there was minimal pilot compensation required for desired performance. Overall, the best performance, I felt it was fairly tight as far as the precision. I did have just a little bit of a problem with my vertical control during the approach to the glidepath and the initial part of the descent. There seemed to be a little bit of a disagreement with the airspeed indicator versus the command bar in the velocity control mode. The bar seems to be somewhat noisy and moves around a little bit and . . . but, once I ignored that, and just used the airspeed as a cross-check, I had a little more faith in the velocity-hold system than I had initially, it seemed to be okay. I just, in general, almost ignored the horizontal command bar.

No real problem on acquiring or tracking on the azimuth; again, I found the command bar to be very helpful. It gave me almost a single point of reference on the ADI and I was able to have enough time to cross-check airspeed, vertical speed, and the HSI for my situation. Overall, minimal pilot compensation required, and I will give it a three.

Single Pilot: Missed Approach

Okay, overall I think I would give this a four, also. I obtained my desired performance, but it was requiring moderate pilot compensation and pilot effort in the cockpit. The flight-control system, as was mentioned by Cal Copter, is pretty good. That velocity-hold system really helps me, especially in the turns or doing the additional tasks within the cockpit.

On the go-around, I initially went to the go-around mode to get established on the outbound heading of 183, received the opposite . . . clearance, which required me to turn back to the north, inbound to Santa Barbara, and at that time, I went to the

center position with the go-around select switch, and my vertical bar just went off to the side. I didn't use that again. There should be some kind of a manual flight director mode, also, just on the basic setup of the cockpit that would be tied to the heading mode of the HSI. We don't have that, though, so the remainder of the task was done basically with raw data, although the vertical . . . the velocity-hold system did work. Overall I think that the flight-control system was adequate, the airspeed velocity-hold system is excellent, and really helped. Just from the additional tasks, I would give it a four.

Single Pilot: Continued Approach

Okay, I would have to give that overall a four in that it required a moderate pilot compensation just from the workload in the cockpit during the associated tasks, or the additional tasks. I had no real problem intercepting and tracking. The biggest problem I had was the requirement to do something in the cockpit at several critical times.

One was the deceleration down from 80 to 60, and the other was intercepting the glidepath, and it just seemed that the workload, just at that point, it got awfully busy in here. Again, with the flight-director system, and ignoring that small amount of noise in the horizontal bar, I was able to take care of the associated tasks and come back. There was several times when I did have a relatively healthy deviation on the glidepath and a couple of times on the localizer, but again, I was able to come back to the flight director almost a single point on the instrument panel and recover. I felt very comfortable, but I think that just the overall additional tasks in the cockpit rates it a four.

Researcher: I copy desired performance, but moderate compensation. Is that correct?

Pilot: That's desired performance required moderate compensation, that is true.

Pilot S
Runs 217, 218
Ratings: DP = 3; SPMA = 3-1/2

Dual Pilot

I will give it a three — somewhere between a two and a three — that's how I read it here, a little bit over the . . . that airspeed function makes it much, much easier. I rate it as a three.

Single Pilot: Missed Approach

Considering you can have some differences as far as ordering the priorities for the tasks, if somebody really wanted to, they would get worried about making all the exact procedural calls and setting up all the pilot cockpit tasks as opposed to flying the airplane. I could see where that could affect your ratings, as opposed to trying to fly the airplane and then doing the other things as you get around to them. I think that, again, would be a three.

I guess I should change my mind on that other. It really wouldn't make much sense — that being single-pilot and the previous one being a three too, for the same configuration. That has to be a four then. There's not a whole hell of a lot of difference, maybe, make it a three and a half. It is not that bad, really.

CONFIGURATION T30

Pilot M
Runs 83-85
Ratings: DP = 5; SPMA = 6; SPCA = 5

Dual Pilot

Overall I would give that a five, that was with raw-data system. It requires considerable pilot compensation. Again, I had to really tighten up on the cross-check, but I think the biggest factor was slowing down and then getting established at 60 knots. Lateral axis — again, the azimuth seemed to give me most of the problem. I was making some healthy inputs to that, but I didn't have any other associated tasks in the cockpit; I could really concentrate on the HSI and cross-check on the vertical speed and the other instruments. I was able to, in my opinion, adequately perform the task, but it did require quite a bit of concentration and a very tight cross-check on my part. Overall a five.

Single Pilot: Missed Approach

I think I would give that task a six. That extensive pilot compensation was required. The additional tasks in the cockpit, mainly, and although I knew that the frequency was 114.9, I went over and I was in a hurry and tuned 114.1. No real problem with the transponder this time. I think this is overall a six, for the controllability on that particular one was not really in question. I felt I was in full control, but it was just again the tightness of the cross-check that was required, and I think just breaking down the additional tasks and the small bits and remembering that you had to maintain aircraft control first was the biggest factor. Overall, a six.

Single Pilot: Continued Approach

Okay, I think I would give that one a five as an overall rating. It required considerable pilot compensation, but again, taking the missed approach task away and everything was pretty well expected. I was able to stabilize, again, on airspeed. At one point, I was about 12 knots slow but, again, able to recover by just going to the attitude indicator and really concentrating, cross-checking. The intensity of the cross-check is the main reason for the five. I think it was considerable pilot compensation required.

Pilot K
Runs 190-192
Ratings: DP = 5-1/2; SPMA = 7; SPCA = 6

Dual Pilot

On that one the workload was certainly higher than the models I have seen. I missed the attitude attention in roll and pitch quite a bit. You really couldn't take your eyes off the control task. You couldn't really divorce the control task and say, "All right, I'm just going to relax for awhile." I had to be right on it all the time, especially in pitch.

However, I think this one could be flown with considerable pilot compensation for a two pilot case of the control task. I would have to give it a five and a half for a two-pilot task. There's probably not extensive pilot compensation, but I have to say that it is more than considerable.

Single Pilot: Missed Approach

This one was another case where you could not really do the control task and the auxiliary tasks separately — too hard to maintain the control task, keep an eye on the cross-check going as you were dialing the radio frequency changes, and so forth.

Because of the foregoing, I feel that with maximum tolerable compensation, I don't think much of my performance was adequate in this case. I'll have to give that one a seven.

Single Pilot: Continued Approach

I don't know what to do about that one. I think probably, I'd like to give it a six. The reason for it is . . . without the missed approach, I think this one was fairly significant, that the task was probably . . . at least the pitch attitude control task was not as demanding when we missed out on the missed approach procedure. Because of that I would say for this task, the approach task — continued approach, it was probably about a six.

I didn't find I had quite as much problem with pitch-attitude control.

APPENDIX B

STANDARD DEVIATION MEASURES OF FLIGHT PERFORMANCE AND CONTROL USE (35-sec INTERVALS BETWEEN INITIAL APPROACH AND DESCENT SEGMENTS)

TABLE 1.- DUAL-PILOT TASK, LIGHT TURBULENCE, AND WIND DIRECTION CHANGE DURING DESCENT

(a) Configuration T30

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
M	083	Initial approach	0.152	0.206	0.125	0.057	4.83	2.69	63	1.67	1.88	--	0.40	0.90	5.601	0.262
		Descent	.125	.221	.698	.121	2.44	5.42	--	1.32	3.56	0.29	.79	1.07	6.039	.281
		Missed approach	.205	.268	.710	.069	2.56	7.70	--	2.69	3.57	--	--	2.36	8.451	.344
K	190	Initial approach	.223	.231	.244	.122	4.32	4.14	23	2.05	2.06	--	.10	1.05	6.075	.343
		Descent	.187	.320	.256	.107	1.52	2.85	--	1.45	3.35	.09	.57	1.54	3.578	.386
		Missed approach	.337	.347	.745	.130	8.07	10.26	--	4.49	5.72	--	--	3.14	13.426	.501
G	213	Initial approach	.133	.249	.100	.089	2.98	2.79	9	1.17	3.28	--	.06	.99	4.201	.296
		Descent	.254	.296	.261	.150	3.75	7.41	--	3.37	2.58	.26	.37	1.26	8.400	.418
		Missed approach	.190	.231	.520	.284	3.68	5.89	--	2.48	2.18	--	--	2.83	7.500	.412
													Average		7.030	.360

(b) Configuration T01

M	139	Initial approach	0.115	0.178	0.239	0.195	4.74	2.23	6	1.73	1.94	--	0.47	1.92	5.579	0.288
		Descent	.177	.192	.604	.167	5.01	6.31	--	2.65	1.85	0.21	.34	1.31	8.163	.310
		Missed approach	.157	.138	.885	.521	8.01	3.72	--	1.86	.86	--	--	4.38	9.858	.561
													Average		7.867	.386

TABLE 1.- Continued.

(c) Configuration T02

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
M	172	Initial approach	0.090	0.067	0.410	0.022	1.17	3.56	22	0.82	0.74	--	0.02	1.27	3.957	0.114
		Descent	.102	.109	.255	.002	2.66	2.90	--	1.54	.87	0.12	.02	.99	4.058	.149
		Missed approach	.166	.142	.760	.097	3.04	6.92	--	1.86	1.39	--	--	1.23	7.658	.239
G	210	Initial approach	.131	.135	.098	.092	7.10	2.72	10	1.33	.96	--	.01	1.89	7.835	.209
		Descent	.131	.246	.344	.084	1.89	3.53	--	1.28	1.66	.09	.02	1.11	4.155	.291
		Missed approach	.250	.203	.958	.061	3.08	6.82	--	1.80	3.92	--	--	3.71	8.352	.328
K	261	Initial approach	.139	.134	.314	.068	2.51	3.69	15	2.11	1.33	--	.10	1.02	4.578	.205
		Descent	.196	.270	.635	.135	3.01	7.43	--	2.69	2.20	.26	.10	1.48	8.152	.360
		Missed approach	.359	.309	.804	.140	4.54	8.85	--	4.03	2.80	--	--	2.80	10.333	.494
													Average		6.564	.265

(d) Configuration T03

G	067	Initial approach	0.148	0.209	0.197	0.045	7.82	4.26	15	1.77	1.40	--	0.02	1.08	8.970	0.260
		Descent	.291	.217	.079	.059	2.81	6.21	--	3.34	1.07	0.14	.03	.82	6.865	.368
		Missed approach	.365	.233	.872	.087	3.29	6.95	--	3.55	1.10	--	--	2.31	8.029	.433
K	147	Initial approach	.145	.139	.298	.049	8.17	3.91	30	1.92	1.16	--	.06	.99	9.111	.207
		Descent	.316	.205	.526	.080	4.45	7.75	--	3.63	1.70	.21	.07	1.30	9.031	.385
		Missed approach	.418	.265	.713	.140	8.71	8.37	--	5.80	2.34	--	--	4.61	12.930	.514

TABLE 1.- Continued.

(d) Configuration T03 (Continued)

Pilot	Run	Segment	Standard deviation											Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
M	281	Initial approach	0.100	0.146	0.284	0.072	5.51	4.24	16	2.01	1.13	--	0.08	1.37	7.086	0.191
		Descent	.173	.163	.281	.040	2.97	5.36	--	2.78	1.15	0.14	.03	.61	6.158	.241
		Missed approach	.163	.179	.759	.053	3.09	6.00	--	2.29	2.54	--	--	2.56	7.218	.248
													Average		8.378	.316
(e) Configuration T05																
G	292	Initial approach	0.125	0.202	0.179	0.051	2.91	3.62	16	1.35	2.54	--	0.11	1.26	4.812	0.243
		Descent	.124	.155	.207	.176	3.69	3.62	--	1.21	2.07	0.11	.78	2.22	5.626	.265
		Missed approach	.134	.120	.435	.127	5.40	7.42	--	2.37	1.93	--	--	1.04	9.236	.220
K	299	Initial approach	.063	.134	.181	.077	2.83	1.23	3	.40	1.66	--	.24	1.06	3.263	.167
		Descent	.132	.109	.132	.060	5.19	2.10	--	1.24	2.21	.06	.59	1.68	5.845	.181
		Missed approach	.121	.160	.807	.238	5.13	6.99	--	1.49	1.87	--	--	1.36	8.776	.311
													Average		6.260	.231
(f) Configuration T07																
G	290	Initial approach	0.135	0.152	0.718	0.064	3.48	4.87	44	1.88	1.16	--	0.03	1.36	6.138	0.213
		Descent	.107	.105	.346	.063	4.44	3.16	--	1.56	.69	0.11	.04	1.41	5.629	.163
		Missed approach	.037	.214	.682	.025	2.59	4.85	--	.43	4.93	--	--	1.31	5.652	.219

TABLE 1.- Continued.

(f) Configuration T07 (Continued)

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
K	297	Initial approach	0.129	0.121	0.212	0.072	5.09	2.83	10	1.65	1.31	--	0.08	0.98	5.906	0.191
		Descent	.146	.085	.346	.055	4.01	3.49	--	1.55	.80	0.14	.04	1.68	5.575	.178
		Missed approach	.175	.165	.944	.130	4.31	6.78	--	1.88	2.04	--	--	3.58	8.796	.273
M	305	Initial approach	.124	.043	.628	.074	5.98	5.46	30	1.43	.48	--	.14	2.84	8.581	.151
		Descent	.146	.049	.568	.090	6.29	3.09	--	1.25	.59	.13	.07	2.85	7.565	.178
		Missed approach	.075	.049	.836	.076	2.82	6.50	--	1.13	.51	--	--	1.59	7.262	.117
													Average		6.789	.187
		(g) Configuration T08														
M	307	Initial approach	0.139	0.067	0.674	0.070	8.16	5.60	32	1.58	0.75	--	0.03	1.52	10.013	0.169
		Descent	.045	.063	.471	.035	1.74	4.50	--	.32	.51	0.12	.05	1.38	5.018	.085
		Missed approach	.158	.053	.697	.075	2.64	6.51	--	2.06	.41	--	--	2.23	7.370	.183
													Average		7.467	.146
		(h) Configuration T10														
M	093	Initial approach	0.065	0.095	0.232	0.038	1.14	1.91	31	1.06	1.21	--	0.12	0.83	2.374	0.121
		Descent	.047	.167	.341	.199	1.68	3.41	--	.79	1.89	0.12	.54	1.78	4.197	.264
		Missed approach	.204	.078	.844	.092	2.71	7.61	--	2.29	.82	--	--	1.83	8.283	.237

TABLE 1.- Continued.

(h) Configuration T10 (Continued)

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
K	186	Initial approach	0.135	0.211	0.111	0.084	3.58	2.43	5	1.32	1.55	--	0.19	1.14	4.474	0.264
		Descent	.337	.269	.334	.161	4.11	7.00	--	3.83	2.12	0.12	.98	.85	8.162	.460
		Missed approach	.299	.279	.778	.091	3.54	9.30	--	3.58	3.13	--	--	2.67	10.303	.419
													Average		6.299	.294
(i) Configuration T11																
M	136	Initial approach	0.150	0.181	0.665	0.153	3.74	4.83	27	1.80	2.12	--	0.41	1.33	6.252	0.280
		Descent	.161	.180	.466	.109	3.46	4.10	--	2.53	2.02	0.18	.81	.81	5.426	.265
		Missed approach	.206	.186	1.015	.293	2.72	7.97	--	2.09	2.16	--	--	1.02	8.483	.404
													Average		6.720	.316
(j) Configuration T12																
M	169	Initial approach	0.187	0.164	0.509	0.131	2.95	7.80	49	3.13	1.34	--	0.21	1.64	8.499	0.281
		Descent	.145	.141	.556	.111	4.82	4.17	--	2.19	1.21	0.14	.11	1.23	6.491	.231
		Missed approach	.179	.123	.606	.074	2.31	6.66	--	2.00	.80	--	--	1.57	7.222	.229
G	286	Initial approach	.193	.174	.223	.136	5.25	4.44	13	2.26	1.25	--	0.05	1.32	7.001	.293
		Descent	.121	.133	.130	.059	3.14	3.50	--	1.27	.77	.08	.05	1.15	4.841	.189
		Missed approach	.268	.127	.785	.144	8.98	8.26	--	4.06	.70	--	--	2.11	12.382	.330

TABLE 1.- Continued.

(j) Configuration T12 (Continued)

Pilot	Run	Segment	Standard deviation											Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
K	295	Initial approach	0.458	0.133	0.575	0.069	6.40	7.63	36	5.53	1.25	--	0.27	2.55	10.280	0.482
		Descent	.245	.161	.436	.139	6.35	5.57	--	2.99	.99	0.22	.07	2.15	8.716	.324
		Missed approach	.334	.186	.773	.172	5.37	8.03	--	4.29	1.37	--	--	3.07	10.136	.419
													Average		8.396	.309

(k) Configuration T13

M	009	Initial approach	0.146	0.125	0.370	0.199	8.28	3.62	30	1.55	0.59	--	0.02	3.02	9.528	0.277
		Descent	.237	.170	.300	.109	2.65	5.10	--	3.21	.74	0.26	.03	.91	5.819	.311
		Missed approach	.331	.351	.857	.348	2.70	9.21	--	2.83	2.57	--	--	2.53	9.925	.595
G	023	Initial approach	.289	.184	.343	.150	8.35	7.30	34	3.18	1.02	--	.04	2.10	11.288	.374
		Descent	.273	.192	.172	.051	2.40	4.70	--	2.58	.93	.16	.03	.93	5.359	.338
		Missed approach	.547	.392	.566	.110	5.35	9.02	--	6.09	3.86	--	--	2.99	10.905	.682
K	150	Initial approach	.110	.128	.347	.038	4.54	3.95	25	1.97	1.98	--	.06	.70	6.058	.173
		Descent	.151	.269	.336	.059	1.98	3.69	--	1.55	3.52	.36	.23	1.70	4.520	.314
		Missed approach	.372	.249	.488	.476	10.24	3.15	--	5.42	3.88	--	--	13.23	17.024	.653
													Average		8.936	.413

TABLE 1.- Continued.

(l) Configuration T15

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
M	040	Initial approach	0.055	0.095	0.068	0.035	1.03	0.43	2	0.41	1.30	--	0.14	0.72	1.328	0.115
		Descent	.149	.155	.431	.033	2.87	5.91	--	2.16	1.60	0.22	.19	1.55	6.750	.218
		Missed approach	.289	.245	.777	.135	10.52	11.57	--	4.46	3.82	--	--	9.09	18.088	.402
G	057	Initial approach	.093	.214	.147	.039	1.70	2.10	12	1.29	2.48	--	.10	1.78	3.235	.237
		Descent	.183	.191	.272	.134	4.40	5.91	--	2.27	1.76	.23	.19	1.98	7.629	.297
		Missed approach	.281	.241	.565	.118	5.70	10.39	--	3.86	1.93	--	--	1.10	11.902	.389
K	236	Initial approach	.168	.186	.631	.047	3.90	3.62	14	1.22	1.53	--	.12	.72	5.370	.255
		Descent	.210	.167	.205	.051	2.78	4.92	--	2.18	1.47	.10	.15	1.04	5.746	.273
		Missed approach	.211	.189	.645	.079	4.09	6.25	--	2.64	2.22	--	--	2.99	8.046	.294
													Average		7.566	.276

(m) Configuration T16

M	034	Initial approach	0.064	0.092	0.222	0.226	2.75	2.66	13	1.48	1.54	--	0.61	2.70	4.683	0.252
		Descent	.185	.154	.174	.180	2.61	4.10	--	2.24	2.19	0.12	1.08	2.48	5.456	.301
		Missed approach	.271	.107	.693	.089	4.54	8.72	--	3.16	3.75	--	--	4.01	10.617	.305
M	043	Initial approach	.100	.078	.153	.039	4.66	2.57	13	1.38	1.10	--	.58	.69	5.366	.133
		Descent	.139	.169	.294	.099	4.32	4.62	--	2.18	2.33	.16	.69	2.77	6.905	.240
		Missed approach	.280	.206	.795	.094	2.88	8.65	--	2.48	2.09	--	--	2.56	9.469	.360
													Average		7.083	.265

TABLE 1.- Continued.

(n) Configuration T17

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
M	030	Initial approach	0.119	0.108	0.142	0.040	2.46	4.45	17	2.09	2.05	--	0.10	0.66	5.127	0.166
		Descent	.117	.113	.360	.025	1.84	2.76	--	1.07	.59	0.13	.04	1.70	3.727	.165
		Missed approach	.144	.240	.505	.190	2.09	6.74	--	1.38	3.78	--	--	2.66	7.541	.338
G	207	Initial approach	.204	.127	.508	.110	8.52	4.59	28	2.32	.90	--	.04	1.61	9.811	.264
		Descent	.175	.144	.499	.094	2.78	5.24	--	1.80	.88	.16	.02	1.06	6.026	.245
		Missed approach	.228	.302	1.131	.144	2.33	8.69	--	2.06	3.87	--	--	1.35	9.098	.405
M	302	Initial approach	.140	.073	.442	.124	4.67	5.13	20	2.46	.83	.22	.05	2.68	7.437	.201
		Descent	.091	.085	.797	.086	4.60	4.96	--	1.77	.66	.19	.08	4.66	8.214	.151
		Missed approach	.120	.050	1.083	.060	3.44	8.05	--	1.28	.47	--	--	2.71	9.164	.143
													Average		7.349	.231

(o) Configuration T18

M	046	Initial approach	0.219	0.106	0.471	0.105	8.08	8.76	39	3.60	1.07	--	0.03	1.67	12.034	0.265
		Descent	.236	.137	.442	.064	2.52	6.28	--	2.71	.66	0.23	.03	1.25	6.881	.280
		Missed approach	.192	.238	.650	.200	2.66	8.51	--	1.88	3.17	--	--	3.32	9.514	.365
G	060	Initial approach	.154	.209	.527	.105	7.80	6.77	38	2.48	1.98	--	.05	1.01	10.378	.280
		Descent	.342	.225	.313	.073	2.81	7.58	--	3.74	1.02	.17	.01	1.77	8.276	.416
		Missed approach	.308	.230	.802	.059	2.12	8.21	--	3.25	3.78	--	--	1.87	8.683	.389

TABLE 1.- Continued.

(o) Configuration T18 (Continued)

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
K	242	Initial approach	0.280	0.167	0.250	0.164	7.14	6.68	56	2.82	1.43	--	0.25	1.60	9.908	0.365
		Descent	.213	.133	.240	.070	2.09	2.98	--	1.95	.67	0.07	.02	1.35	3.882	.261
		Missed approach	.399	.301	.669	.153	4.51	8.41	--	4.47	4.47	--	--	5.38	10.955	.523
													Average		8.946	.349

(p) Configuration T20

G	165	Initial approach	0.162	0.182	0.147	0.091	4.71	2.81	9	1.17	1.69	--	0.24	1.81	5.775	0.260
		Descent	.085	.168	.212	.070	1.64	3.15	--	.50	1.32	0.11	.13	1.13	3.727	.201
		Missed approach	.153	.322	.843	.116	2.24	7.12	--	.99	5.21	--	--	1.16	7.554	.375
K	182	Initial approach	.227	.221	.445	.035	4.35	3.42	16	1.60	2.74	--	.19	1.37	5.701	.319
		Descent	.105	.226	.341	.090	1.54	3.65	--	.67	2.02	.14	.63	.78	4.038	.265
		Missed approach	.280	.292	.731	.062	2.28	5.44	--	1.86	3.98	--	--	2.03	6.238	.409
M	279	Initial approach	.067	.111	.231	.061	.97	1.13	20	.45	1.73	--	.08	1.12	1.863	.143
		Descent	.097	.076	.212	.058	1.39	2.25	--	.73	1.29	.08	.14	.89	2.790	.136
		Missed approach	.173	.118	1.038	.129	5.27	7.36	--	1.23	1.29	--	--	2.75	9.461	.246
													Average		5.239	.262

TABLE 1.- Continued.

(q) Configuration T21

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
G	162	Initial approach	0.170	0.282	0.296	0.888	2.26	2.40	3	1.31	2.85	--	0.25	0.91	3.420	0.341
		Descent	.190	.275	.453	.191	4.50	3.92	--	1.39	2.90	0.18	.60	3.39	6.864	.385
		Missed approach	.101	.127	.721	.052	1.88	6.42	--	.75	1.23	--	--	1.00	6.764	.170
													Average		5.683	.299

(r) Configuration T22

M	176	Initial approach	0.083	0.085	0.213	0.013	1.36	1.19	3	0.51	0.77	--	0.05	1.30	2.226	0.120
		Descent	.138	.096	.399	.036	4.75	2.60	--	1.01	.73	.09	.06	3.06	6.220	.172
		Missed approach	.092	.121	.708	.110	2.06	7.20	--	1.12	1.03	--	--	.97	7.551	.188
G	224	Initial approach	.107	.140	.263	.045	5.68	1.36	6	.66	.93	--	.02	.86	5.904	.182
		Descent	.082	.097	.165	.089	3.14	2.62	--	.58	.54	.15	.09	2.00	4.552	.155
		Missed approach	.028	.248	1.003	.057	.96	8.15	--	.52	4.35	--	--	1.79	8.399	.256
K	258	Initial approach	.064	.053	.137	.040	.59	1.01	18	.37	.41	--	.01	.39	1.233	.092
		Descent	.233	.196	.338	.019	6.19	4.72	--	2.03	1.35	.26	.06	.99	7.847	.305
		Missed approach	.156	.224	.861	.082	2.00	8.71	--	1.49	2.55	--	--	1.13	9.008	.285
													Average		5.882	.195

TABLE 1.- Continued.

(s) Configuration T23

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
M	002	Initial approach	0.216	0.140	0.287	0.063	10.04	3.55	16	1.42	1.07	--	0.08	1.82	10.804	0.265
		Descent	.040	.096	.222	.046	1.88	3.28	--	.40	.85	0.07	.06	1.34	4.011	.114
		Missed approach	.192	.191	.874	.077	4.40	11.51	--	2.07	1.74	--	--	3.08	12.701	.282
K	143	Initial approach	.183	.090	.334	.022	8.32	3.89	29	1.38	.78	--	.04	1.33	9.280	.205
		Descent	.106	.109	.214	.020	2.03	3.60	--	.83	.76	.16	.02	1.40	4.364	.153
		Missed approach	.163	.240	1.017	.025	2.55	9.15	--	1.60	4.17	--	--	1.68	9.646	.291
													Average		8.468	.218

(t) Configuration T25

M	079	Initial approach	0.117	0.145	0.218	0.014	1.32	4.01	19	1.88	2.33	--	0.18	0.71	4.281	0.187
		Descent	.036	.132	.317	.040	1.11	3.73	--	1.26	1.76	0.24	.15	.76	3.965	.143
		Missed approach	.215	.110	.670	.092	1.72	7.38	--	1.30	2.85	--	--	1.21	7.674	.258
G	090	Initial approach	.112	.194	.350	.069	2.65	3.95	32	2.23	1.90	--	.09	.81	4.825	.234
		Descent	.070	.322	.222	.127	1.32	3.60	--	1.35	3.67	.10	1.20	1.20	4.018	.353
		Missed approach	.055	.113	1.020	.030	1.12	9.02	--	1.45	1.00	--	--	1.00	9.144	.129
M	097	Initial approach	.008	.116	.148	.131	.66	1.84	13	.62	1.50	--	.25	1.59	2.520	.175
		Descent	.016	.134	.367	.261	1.51	4.29	--	1.90	2.84	.13	.90	2.49	5.185	.294
		Missed approach	.038	.146	.929	.220	1.28	6.86	--	1.46	2.67	--	--	2.60	7.447	.267

TABLE 1.- Continued.

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
(t) Configuration T25 (Continued)																
K	265	Initial approach	0.096	0.215	0.715	0.045	1.99	2.44	16	1.74	2.81	--	0.46	0.73	3.232	0.240
		Descent	.095	.250	.347	.102	2.11	2.95	--	1.12	3.51	0.08	1.23	1.11	3.793	.286
		Missed approach	.020	.005	1.089	.020	1.17	9.02	--	1.48	.47	--	--	1.02	9.153	.029
													Average		5.436	.216
(u) Configuration T26																
G	087	Initial approach	0.156	0.177	0.577	0.035	9.48	4.62	18	2.28	1.52	--	0.37	0.85	10.580	0.239
		Descent	.116	.246	.194	.094	2.35	4.34	--	1.48	2.45	0.10	.16	.76	4.994	.288
		Missed approach	.150	.194	.137	.049	1.53	11.17	--	1.66	2.03	--	--	1.36	11.356	.250
													Average		8.977	.259
(v) Configuration T27																
G	228	Initial approach	0.171	0.090	0.473	0.041	3.33	6.10	58	2.56	0.67	--	0.05	1.33	7.076	0.198
		Descent	.043	.099	.254	.048	1.30	3.12	--	1.40	.71	0.22	.01	.90	3.498	.118
		Missed approach	.352	.311	1.212	.089	3.64	10.34	--	2.46	4.70	--	--	1.42	11.054	.478
M	283	Initial approach	.116	.090	.053	.131	1.27	2.25	13	.87	.83	--	.05	1.15	2.828	.197
		Descent	.004	.105	.437	.124	1.49	3.24	--	1.49	.90	.19	.08	1.71	3.955	.163
		Missed approach	.003	.015	.807	.076	1.31	7.22	--	1.48	.46	--	--	.73	7.374	.078
													Average		5.964	.205

TABLE 1.- Concluded.

(w) Configuration T28

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
G	071	Initial approach	0.171	0.141	0.306	0.049	9.65	5.30	21	2.42	1.20	--	0.08	1.39	11.097	0.227
		Descent	.088	.086	.528	.054	1.18	4.19	--	1.17	.44	0.25	.06	.95	4.455	.134
		Missed approach	.039	.060	1.293	.085	1.02	6.57	--	.91	.65	--	--	1.33	6.780	.111
M	075	Initial approach	.183	.042	.243	.029	8.68	6.30	21	3.12	.49	--	.05	1.06	10.778	.190
		Descent	.011	.062	.266	.015	1.34	4.08	--	1.49	.57	.13	.03	.81	4.370	.065
		Missed approach	.013	.217	.728	.177	1.14	6.02	--	.97	3.76	--	--	1.22	6.247	.280
													Average		7.288	.168

TABLE 2.- SINGLE-PILOT TASK, LIGHT TURBULENCE, AND WIND DIRECTION CHANGE DURING DESCENT: MISSED APPROACH

(a) Configuration T30

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
M	084	Initial approach	0.164	0.174	0.087	0.080	4.72	3.21	6	1.74	2.58	--	0.24	1.92	6.022	0.252
		Descent	.178	.164	.481	.094	2.50	5.43	--	2.40	1.89	0.16	.40	1.80	6.243	.260
		Missed approach	.203	.338	.801	.131	7.56	8.19	--	3.00	3.84	--	--	1.55	11.253	.415
K	191	Initial approach	.170	.294	.177	.110	5.86	5.36	40	2.65	3.12	--	.35	1.11	8.019	.357
		Descent	.287	.392	.655	.154	4.69	7.65	--	2.99	5.35	.23	.50	1.22	9.056	.510
		Missed approach	.355	.328	.986	.079	6.93	9.86	--	3.37	3.25	--	--	2.74	12.359	.490
G	214	Initial approach	.134	.194	.303	.120	2.73	2.58	41	1.01	2.17	--	.31	1.89	4.205	.265
		Descent	.214	.232	.250	.236	4.68	6.20	--	3.47	2.92	.39	.81	2.47	8.151	.394
		Missed approach	.224	.249	.616	.388	4.44	7.49	--	2.80	3.51	--	--	3.71	9.465	.513
													Average		8.308	.384

(b) Configuration T01

M	140	Initial approach	0.216	0.290	0.232	0.155	6.79	4.67	17	3.00	3.69	--	0.53	2.36	8.572	0.393
		Descent	.201	.331	.211	.085	5.55	7.52	--	4.17	4.46	0.22	.69	1.31	9.438	.396
		Missed approach	.240	.179	.850	.103	6.65	8.49	--	3.93	2.40	--	--	2.39	11.046	.317
													Average		9.685	.369

TABLE 2.- Continued.

(c) Configuration T02

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
M	174	Initial approach	0.182	0.410	0.102	0.097	2.16	3.17	17	2.20	8.95	--	0.45	2.14	4.393	0.459
		Descent	.299	.133	.976	.105	7.90	6.17	--	2.80	.88	0.25	.08	2.09	10.239	.344
		Missed approach	.221	.222	.953	.073	4.26	5.53	--	2.17	2.18	--	--	2.54	7.428	.322
G	212	Initial approach	.160	.212	.366	.113	7.64	3.95	16	2.06	2.45	--	.09	.90	8.648	.289
		Descent	.160	.170	.234	.187	1.54	3.26	--	1.49	1.63	.08	.04	2.03	4.138	.299
		Missed approach	.205	.251	.791	.133	1.54	6.16	--	1.64	4.15	--	--	2.58	6.854	.350
K	264	Initial approach	.323	.239	.234	.077	9.07	6.63	29	4.92	2.00	--	.07	1.77	11.373	.409
		Descent	.423	.258	.829	.118	6.44	9.81	--	5.25	3.61	.23	.16	2.03	11.909	.509
		Missed approach	.355	.210	.790	.089	3.80	7.72	--	3.78	3.25	--	--	3.78	9.398	.422
													Average		8.264	.378

(d) Configuration T03

G	068	Initial approach	0.203	0.215	0.329	0.096	7.38	6.59	43	2.95	1.99	--	0.04	1.05	9.950	0.311
		Descent	.306	.189	.566	.074	5.19	10.34	--	4.87	1.30	0.33	.04	2.09	11.757	.367
		Missed approach	.447	.230	1.059	.212	5.58	10.57	--	5.90	1.34	--	--	2.87	12.292	.546
K	148	Initial approach	.176	.139	.508	.064	7.76	7.19	36	2.42	.89	--	.05	.79	10.608	.233
		Descent	.594	.458	.600	.123	9.63	15.84	--	8.80	8.13	.78	.43	1.83	18.628	.760
		Missed approach	.472	.312	.423	.218	4.58	10.04	--	5.76	2.69	--	--	2.38	11.289	.606

TABLE 2.- Continued.

(d) Configuration T03 (Continued)

Pilot	Run	Segment	Standard deviation											Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
M	282	Initial approach	0.148	0.186	0.191	0.038	6.36	5.11	27	2.37	1.77	--	0.06	0.85	8.203	0.241
		Descent	.133	.186	.476	.046	1.80	4.55	--	1.30	1.88	.23	.06	1.39	5.087	.233
		Missed approach	.299	.149	.832	.129	4.46	8.55	--	5.01	1.21	--	--	1.68	9.789	.358
													Average		10.845	.406
(e) Configuration T05																
G	293	Initial approach	0.096	0.171	0.061	0.077	3.22	3.10	19	1.61	2.39	--	0.15	1.21	4.631	0.211
		Descent	.043	.133	.165	.095	2.94	2.02	--	.29	1.90	0.07	.18	1.08	3.727	.169
		Missed approach	.061	.024	.789	.059	4.35	5.72	--	.52	.32	--	--	1.09	7.268	.088
K	300	Initial approach	.005	.065	.093	.087	4.88	1.06	32	.12	.54	--	.08	.98	5.089	.109
		Descent	.154	.219	.478	.104	5.11	4.15	--	1.89	3.36	.38	.28	.98	6.655	.287
		Missed approach	.094	.500	.509	.260	2.30	5.61	--	1.62	7.24	--	--	3.24	6.875	.571
													Average		5.708	.239
(f) Configuration T07																
G	291	Initial approach	0.103	0.108	0.610	0.043	8.88	4.02	16	1.95	1.10	--	0.06	1.15	9.815	0.155
		Descent	.068	.212	.706	.079	3.72	4.07	--	.78	2.17	0.23	.09	1.01	5.606	.236
		Missed approach	.086	.106	.426	.023	4.54	6.54	--	2.18	4.48	--	--	.98	8.021	.138

TABLE 2.- Continued.

(f) Configuration T07 (Continued)

Pilot	Run	Segment	Standard deviation											Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
K	298	Initial approach	0.140	0.147	0.507	0.095	3.85	1.48	54	2.12	1.40	--	0.04	2.77	4.968	0.224
		Descent	.210	.185	.522	.082	4.49	6.92	--	2.84	2.38	0.17	.14	1.73	8.428	.292
		Missed approach	.337	.182	.767	.106	6.56	9.18	--	4.03	5.34	--	--	5.86	12.714	.397
M	306	Initial approach	.096	.088	.678	.075	2.40	3.56	39	1.48	.78	--	.09	.74	4.357	.150
		Descent	.265	.219	1.086	.178	6.89	8.42	--	3.74	2.76	.36	.09	1.82	11.031	.387
		Missed approach	.072	.022	.324	.093	2.84	4.17	--	1.50	.33	--	--	1.12	5.168	.120
													Average		7.790	.233
(g) Configuration T08																
M	308	Initial approach	0.121	0.070	0.611	0.029	8.27	3.88	34	1.58	0.74	--	0.05	1.43	9.246	0.143
		Descent	.089	.133	.401	.089	1.39	3.27	--	.76	1.49	0.09	.05	1.19	3.747	.183
		Missed approach	.127	.022	.780	.075	1.33	7.53	--	1.88	.30	--	--	1.02	7.714	.149
													Average		6.903	.158
(h) Configuration T10																
M	094	Initial approach	0.140	0.064	0.432	0.038	9.52	2.63	9	2.63	0.61	--	0.08	1.57	10.001	0.159
		Descent	.190	.144	.665	.133	4.46	7.32	--	2.88	1.97	0.22	.71	1.69	8.737	.273
		Missed approach	.318	.115	.993	.101	6.20	9.88	--	4.93	1.59	--	--	3.46	12.167	.353

TABLE 2.- Continued.

(h) Configuration T10 (Continued)

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
K	188	Initial approach	0.399	0.160	0.076	0.086	5.88	8.06	38	5.38	1.83	--	0.39	1.42	10.077	0.438
		Descent	.245	.281	.318	.158	4.13	4.24	--	2.20	2.65	.14	.56	1.84	6.198	.405
		Missed approach	.317	.157	.996	.120	5.76	7.91	--	3.36	1.57	--	--	3.20	10.295	.374
													Average		9.579	.334
(i) Configuration T11																
M	137	Initial approach	0.160	0.193	0.122	0.145	1.93	3.34	11	2.35	2.01	--	0.52	1.85	4.278	0.290
		Descent	.227	.170	.861	.200	6.71	5.98	--	2.66	1.35	0.28	.14	1.31	9.083	.347
		Missed approach	.260	.102	1.187	.131	4.76	9.92	--	3.00	1.24	--	--	2.01	11.185	.308
													Average		8.182	.315
(j) Configuration T12																
M	170	Initial approach	0.160	0.178	0.244	0.082	3.26	4.98	27	2.45	1.54	--	0.11	1.54	6.148	0.253
		Descent	.138	.170	.355	.074	3.12	4.94	--	2.13	1.23	0.26	.04	.95	5.920	.231
		Missed approach	.253	.092	.979	.145	6.60	6.98	--	2.07	.69	--	--	1.95	9.802	.306
G	287	Initial approach	.140	.115	.424	.156	4.54	3.43	24	1.96	1.20	--	.03	1.03	5.783	.239
		Descent	.177	.119	.371	.098	4.23	5.75	--	2.09	.86	.18	.05	1.97	7.405	.235
		Missed approach	.197	.171	.559	.179	3.56	5.52	--	2.04	.80	--	--	1.44	6.724	.316

TABLE 2.- Continued.

(j) Configuration T12 (Continued)

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
K	296	Initial approach	0.237	0.135	0.901	0.126	4.46	5.00	27	2.87	0.91	--	0.21	1.55	6.877	0.300
		Descent	.256	.145	.358	.173	5.84	5.22	--	2.61	1.03	0.15	.05	2.95	8.370	.453
		Missed approach	.227	.226	.715	.237	5.84	6.83	--	2.82	2.41	--	--	2.63	9.363	.398
													Average		7.377	.304
		(k) Configuration T13														
M	010	Initial approach	0.432	0.205	0.231	0.069	14.24	9.57	22	7.02	1.61	--	0.07	2.24	17.303	0.483
		Descent	.336	.283	.304	.029	6.12	9.40	--	4.70	2.49	0.25	.19	1.47	11.313	.440
		Missed approach	.386	.379	.866	.206	4.55	9.41	--	4.15	3.69	--	--	2.56	10.761	.579
G	024	Initial approach	.364	.187	.313	.108	7.57	7.62	29	3.97	.87	--	.01	1.35	10.826	.423
		Descent	.402	.264	.384	.145	2.71	8.99	--	4.13	1.33	.16	.05	1.78	9.557	.502
		Missed approach	.461	.436	.754	.085	2.90	10.84	--	4.45	3.90	--	--	3.73	11.825	.640
K	151	Initial approach	.201	.059	.216	.018	7.63	5.05	21	2.48	.58	--	.05	.72	9.178	.210
		Descent	.477	.138	.331	.063	10.12	11.36	--	8.26	1.48	.30	.12	1.84	15.325	.501
		Missed approach	.429	.262	1.013	.135	4.29	9.08	--	4.34	2.59	--	--	3.10	10.510	.520
													Average		11.844	.478

TABLE 2.- Continued.

(l) Configuration T15

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
M	041	Initial approach	0.071	0.111	0.276	0.046	1.67	4.56	23	0.87	1.19	--	0.21	0.68	4.904	0.140
		Descent	.230	.165	.221	.070	7.69	8.42	--	4.05	2.09	0.25	.18	.70	11.425	.292
		Missed approach	.358	.161	.627	.051	6.63	7.59	--	3.73	1.59	--	--	2.31	10.339	.396
G	058	Initial approach	.203	.172	.137	.061	3.09	4.13	14	2.58	1.55	--	.03	2.04	5.547	.273
		Descent	.237	.263	.042	.076	3.95	4.45	--	3.06	3.56	.13	.46	3.71	7.012	.362
		Missed approach	.190	.263	.557	.233	2.52	7.91	--	2.36	3.36	--	--	2.02	8.544	.399
K	237	Initial approach	.117	.127	.405	.043	2.69	2.64	18	.86	1.06	--	.14	.71	3.835	.178
		Descent	.157	.252	.260	.125	2.76	5.74	--	2.41	2.10	.21	.33	1.85	6.632	.322
		Missed approach	.130	.235	.632	.218	4.91	6.97	--	1.79	2.40	--	--	2.36	8.846	.346
													Average		7.454	.301

(m) Configuration T16

M	035	Initial approach	0.289	0.163	0.608	0.129	4.93	7.44	36	2.39	2.52	--	0.70	2.37	9.234	0.356
		Descent	.291	.218	.614	.111	8.39	5.36	--	3.37	2.45	0.33	.53	2.74	10.326	.380
		Missed approach	.356	.217	.810	.103	8.36	11.36	--	4.24	3.22	--	--	1.89	14.231	.429
M	045	Initial approach	.133	.149	.196	.164	1.68	4.37	15	1.20	2.28	--	.80	2.14	5.148	.258
		Descent	.181	.163	.267	.026	2.48	5.26	--	2.71	2.53	.16	.32	1.07	5.913	.245
		Missed approach	.442	.153	.527	.061	5.36	9.99	--	5.20	1.48	--	--	4.06	12.042	.472

TABLE 2.- Continued.

(m) Configuration T16 (Continued)

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
K	240	Initial approach	0.269	0.278	0.324	0.086	3.78	4.44	52	3.52	3.96	--	0.37	3.53	6.816	0.396
		Descent	.249	.275	.664	.177	4.59	7.36	--	3.35	3.44	0.14	.84	1.32	8.774	.411
		Missed approach	.109	.264	.604	.116	3.34	7.28	--	2.60	2.86	--	--	1.96	8.246	.308
													Average		8.970	.362
(n) Configuration T17																
M	031	Initial approach	0.106	0.101	0.056	0.024	1.27	2.28	14	1.17	1.68	--	0.08	0.65	2.690	0.148
		Descent	.174	.149	.332	.028	3.40	5.98	--	2.31	1.67	0.26	.08	.89	6.936	.231
		Missed approach	.157	.282	.655	.171	7.04	8.85	--	2.09	4.05	--	--	6.97	9.908	.365
G	208	Initial approach	.145	.147	.380	.175	6.72	3.37	22	1.51	1.63	--	.03	1.72	7.712	.271
		Descent	.149	.157	.343	.131	2.78	6.10	--	1.51	1.37	.08	.04	1.25	6.819	.253
		Missed approach	.168	.250	.583	.147	1.65	7.04	--	2.17	3.95	--	--	.92	7.289	.335
M	303	Initial approach	.171	.107	.611	.075	2.80	6.82	28	2.51	1.46	--	.07	2.75	7.869	.215
		Descent	.152	.072	.631	.110	3.38	5.56	--	1.63	.52	.21	.03	2.38	6.928	.201
		Missed approach	.164	.066	.985	.048	2.52	7.84	--	1.82	.45	--	--	1.51	8.372	.183
													Average		7.169	.245

TABLE 2.- Continued.

(o) Configuration T18

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
M	047	Initial approach	0.243	0.136	0.285	0.044	7.76	7.06	32	3.03	0.96	--	0.03	0.98	10.537	0.282
		Descent	.241	.176	.563	.061	3.19	6.52	--	2.14	1.31	0.29	.05	1.70	7.455	.305
		Missed approach	.246	.153	.508	.035	1.38	6.43	--	2.18	3.94	--	--	1.87	6.837	.292
G	061	Initial approach	.310	.135	.197	.081	7.22	5.33	21	3.10	1.03	--	.03	1.44	9.089	.348
		Descent	.188	.170	.398	.059	1.71	4.18	--	1.98	.78	.20	.02	1.61	4.795	.260
		Missed approach	.223	.214	.741	.058	1.61	8.74	--	2.58	3.85	--	--	1.64	9.037	.314
K	243	Initial approach	.173	.163	.414	.055	7.36	6.67	37	1.89	2.04	--	.09	1.21	10.006	.244
		Descent	.365	.153	.835	.133	4.39	11.65	--	4.99	1.00	.31	.03	1.77	12.575	.418
		Missed approach	.318	.344	.544	.099	3.56	7.94	--	3.90	4.42	--	--	2.95	9.188	.479
													Average		8.835	.327

(p) Configuration T20

G	166	Initial approach	0.038	0.184	0.012	0.084	0.96	0.63	3	0.15	2.29	--	0.14	0.77	1.383	0.206
		Descent	.498	.187	.454	.101	8.06	10.37	--	4.54	1.31	0.65	.09	3.79	13.670	.541
		Missed approach	.208	.287	.692	.107	1.83	7.01	--	1.83	3.36	--	--	1.74	7.451	.370
K	183	Initial approach	.135	.167	.452	.025	1.36	2.90	12	.69	2.40	--	.43	.68	3.274	.216
		Descent	.187	.240	.251	.072	1.94	2.52	--	1.35	2.50	.20	.60	1.24	3.413	.313
		Missed approach	.123	.311	.783	.107	2.67	6.17	--	1.00	4.17	--	--	1.75	6.947	.351

TABLE 2.- Continued.

(p) Configuration T20 (Continued)

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
M	280	Initial approach	0.056	0.045	0.389	0.039	1.33	2.47	11	0.50	1.06	--	0.46	0.41	2.835	0.082
		Descent	.157	.180	.102	.042	3.97	1.54	--	1.42	1.90	0.08	.17	1.56	4.535	.243
		Missed approach	.202	.035	.605	.088	5.60	5.78	--	1.61	0.72	--	--	1.62	8.209	.223
													Average		5.746	.283
(q) Configuration T21																
G	164	Initial approach	0.084	0.206	0.130	0.137	2.22	1.75	18	0.47	2.22	--	0.50	1.15	3.052	0.261
		Descent	.055	.152	.171	.156	1.42	1.44	--	.46	1.09	0.06	.33	1.83	2.727	.225
		Missed approach	.263	.139	.928	.258	3.39	7.33	--	1.65	1.58	--	--	2.47	8.445	.394
													Average		4.741	.293
(r) Configuration T22																
M	177	Initial approach	0.103	0.108	0.303	0.126	5.65	2.44	31	0.67	1.45	--	0.13	1.66	6.374	0.195
		Descent	.080	.130	.510	.016	2.08	4.11	--	.47	1.19	0.13	.07	1.38	4.809	.153
		Missed approach	.003	.079	.913	.104	1.57	8.18	--	.68	.53	--	--	1.12	8.404	.131
G	226	Initial approach	.126	.089	.230	.060	5.66	2.97	63	.83	.57	--	.02	2.01	6.700	.166
		Descent	.085	.120	.091	.036	4.15	1.74	--	.40	.77	.08	.03	1.51	4.747	.151
		Missed approach	.146	.302	1.031	.073	2.07	9.94	--	1.61	5.01	--	--	1.89	10.328	.343

TABLE 2.- Continued.

(r) Configuration T22 (Continued)

Pilot	Run	Segment	Standard deviation											Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
K	259	Initial approach	0.088	0.102	0.127	0.024	2.11	0.85	18	0.55	1.19	--	0.10	0.64	2.363	0.137
		Descent	.217	.140	.340	.049	3.16	2.10	--	1.56	.92	0.15	.03	2.22	4.396	.263
		Missed approach	.224	.193	.970	.064	4.26	8.48	--	1.77	3.24	--	--	2.68	9.861	.303
													Average		6.442	.205
(s) Configuration T23																
M	006	Initial approach	0.126	0.155	0.553	0.036	7.72	7.00	33	1.22	0.90	--	0.04	0.88	10.458	0.203
		Descent	.102	.155	.127	.065	1.87	2.60	--	.69	1.01	0.05	.03	1.07	3.377	.167
		Missed approach	.203	.266	.670	.230	2.82	8.33	--	1.25	3.01	--	--	4.44	9.852	.406
K	144	Initial approach	.232	.098	.326	.033	8.64	3.96	23	1.71	.91	--	.11	1.47	9.617	.254
		Descent	.086	.035	.226	.018	1.54	1.88	--	.69	.40	.07	.02	.83	2.568	.095
		Missed approach	.286	.218	.879	.063	4.08	8.08	--	1.93	3.48	--	--	2.34	9.349	.365
G	232	Initial approach	.218	.129	.546	.188	9.07	4.87	29	1.52	1.08	--	.05	2.73	10.651	.315
		Descent	.176	.223	.832	.109	3.72	5.82	--	1.13	1.91	.24	.12	2.68	7.409	.304
		Missed approach	.122	.227	.870	.061	1.49	6.63	--	.93	4.40	--	--	1.78	7.025	.265
													Average		7.812	.264

TABLE 2.- Continued

(t) Configuration T25

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
M	080	Initial approach	0.077	0.146	0.081	0.066	0.82	1.68	27	0.76	1.75	--	0.15	0.96	2.102	0.178
		Descent	.017	.085	.236	.065	1.24	3.49	--	1.37	1.12	0.12	.33	.87	3.805	.108
		Missed approach	.013	.005	.669	.063	1.15	7.78	--	1.50	.41	--	--	1.41	7.990	.065
G	091	Initial approach	.205	.215	.299	.085	3.89	3.64	15	2.30	2.77	--	.26	.96	5.413	.309
		Descent	.298	.183	.052	.077	2.12	5.43	--	2.57	2.57	.30	.48	1.48	6.014	.358
		Missed approach	.151	.181	1.320	.044	1.28	8.86	--	1.17	2.01	--	--	.89	8.996	.240
M	098	Initial approach	.012	.011	.350	.191	.86	2.52	11	.72	5.23	--	.37	1.36	2.990	.192
		Descent	.007	.176	.086	.215	1.31	3.47	--	1.15	2.76	.10	.41	1.89	4.163	.278
		Missed approach	.006	.126	.764	.025	1.46	7.06	--	1.59	1.65	--	--	1.03	7.283	.129
K	267	Initial approach	.183	.154	.502	.111	4.73	2.07	6	2.44	2.04	--	.67	2.87	5.907	.264
		Descent	.022	.157	.411	.143	1.25	4.97	--	1.31	2.29	.11	.81	1.45	5.326	.213
		Missed approach	.011	.254	1.211	.056	1.05	8.48	--	1.08	3.10	--	--	1.16	8.623	.260
													Average		5.718	.216

(u) Configuration T26

G	088	Initial approach	0.128	0.190	0.274	0.100	7.02	4.78	24	2.18	2.44	--	0.40	0.92	8.543	0.250
		Descent	.148	.199	.142	.074	1.47	3.04	--	1.16	2.72	0.12	.32	.93	3.502	.259
		Missed approach	.099	.212	.916	.145	1.35	8.33	--	1.42	2.67	--	--	1.45	8.562	.275
													Average		6.869	.261

TABLE 2.- Concluded.

(v) Configuration T27

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
G	230	Initial approach	0.152	0.170	0.448	0.064	7.05	3.43	22	2.08	1.97	--	0.08	0.94	7.896	0.237
		Descent	.031	.157	.159	.044	1.20	3.59	--	1.28	1.29	0.10	.04	.72	3.853	.166
		Missed approach	.190	.216	1.501	.040	2.43	11.67	--	2.29	4.24	--	--	1.17	11.978	.290
M	284	Initial approach	.029	.080	.409	.065	.74	2.92	27	.52	.99	--	.04	.91	3.147	.107
		Descent	.016	.104	.202	.208	1.31	3.47	--	1.52	1.01	.21	.06	2.51	4.479	.233
		Missed approach	.028	.071	.697	.083	1.32	6.64	--	1.54	.72	--	--	1.30	6.894	.113
													Average		6.374	.191

(w) Configuration T28

G	072	Initial approach	0.222	0.117	0.666	0.080	9.13	5.39	51	2.77	1.23	--	0.07	1.26	10.677	0.263
		Descent	.066	.107	.085	.039	1.14	3.04	--	1.19	1.15	0.07	.05	.73	3.328	.132
		Missed approach	.081	.085	1.087	.034	1.08	7.92	--	1.38	.67	--	--	.82	8.035	.122
M	078	Initial approach	.180	.153	.199	.092	4.03	3.65	14	1.97	2.25	--	.78	1.34	5.600	.254
		Descent	.053	.079	.516	.065	1.04	5.00	--	1.37	.55	.17	.02	1.02	5.208	.115
		Missed approach	.027	.241	.775	.125	1.36	7.41	--	1.59	4.12	--	--	1.01	7.601	.273
													Average		6.742	.193

TABLE 3.- SINGLE-PILOT TASK, LIGHT TURBULENCE, AND WIND DIRECTION CHANGE DURING DESCENT: CONTINUOUS APPROACH

(a) Configuration T30

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
M	085	Initial approach	0.274	0.170	0.323	0.137	5.95	6.67	51	4.11	2.76	--	0.40	1.98	9.155	0.350
		Descent	.168	.319	.319	.111	1.88	6.18	--	2.53	4.98	0.17	.55	1.21	6.572	.377
K	192	Initial approach	.135	.200	.254	.100	2.72	3.15	16	1.52	1.96	--	.18	.85	4.248	.261
		Descent	.182	.270	.187	.267	4.00	2.96	--	1.48	2.82	.17	.48	2.64	5.633	.421
G	215	Initial approach	.157	.297	.532	.173	2.71	4.37	14	1.18	6.28	--	1.84	1.19	5.278	.378
		Descent	.160	.312	.130	.125	3.57	4.31	--	1.95	3.83	.11	.65	1.37	5.762	.372
													Average		6.108	.360

(b) Configuration T01

M	141	Initial approach	0.207	0.226	0.508	0.116	9.55	4.13	32	3.30	2.29	--	0.16	1.35	10.492	0.328
		Descent	.144	.238	.656	.091	2.68	5.98	--	2.16	4.17	0.17	.29	1.27	6.675	.293
													Average		8.583	.310

(c) Configuration T02

M	173	Initial approach	0.203	0.135	0.785	0.077	4.06	5.77	27	3.00	1.21	--	0.05	1.79	7.279	0.256
		Descent	.225	.167	.627	.043	7.39	5.39	--	3.56	1.49	0.20	.07	1.63	9.291	.283
G	211	Initial approach	.119	.156	.229	.073	6.45	5.61	16	2.30	1.42	--	.03	.97	8.603	.209
		Descent	.183	.227	.247	.144	2.62	4.54	--	1.93	1.71	.07	.05	1.31	5.403	.325
K	263	Initial approach	.214	.357	.522	.237	9.04	3.62	53	2.08	4.19	--	.19	2.69	10.103	.479
		Descent	.445	.235	1.053	.223	7.33	13.70	--	5.21	1.33	.40	.04	1.51	15.611	.550
													Average		9.382	.351

TABLE 3.- Continued.

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
(d) Configuration T03																
G	069	Initial approach	0.213	0.204	0.113	0.083	7.98	5.94	33	2.79	1.94	--	0.04	1.70	10.092	0.306
		Descent	.205	.275	.331	.099	2.55	5.79	--	2.66	2.35	0.15	.08	.83	6.381	.357
K	149	Initial approach	.139	.121	.373	.028	7.78	5.85	26	1.96	.88	--	.06	.79	9.766	.186
		Descent	.308	.261	.326	.103	2.80	7.09	--	3.57	2.89	.17	.24	1.55	7.779	.417
													Average		8.505	.317
(e) Configuration T10																
M	095	Initial approach	0.149	0.131	0.101	0.195	2.99	3.84	23	1.81	1.47	--	0.20	1.81	5.192	0.278
		Descent	.223	.232	.806	.278	5.53	4.08	--	2.38	2.40	0.21	.50	1.44	7.021	.425
K	187	Initial approach	.120	.123	.460	.050	2.04	4.08	13	1.21	1.01	--	.07	.82	4.635	.179
		Descent	.234	.255	.292	.150	5.90	3.79	--	2.34	2.51	.19	.65	1.40	7.151	.377
													Average		6.000	.315
(f) Configuration T11																
M	138	Initial approach	0.117	0.125	0.285	0.101	1.31	2.39	19	1.46	0.94	--	0.36	1.19	2.974	0.199
		Descent	.199	.188	.399	.063	6.38	5.89	--	3.43	2.06	0.18	.71	1.01	8.742	.281
													Average		5.858	.240

TABLE 3.- Continued.

(g) Configuration T12

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
M	171	Initial approach	0.069	0.122	0.221	0.075	3.13	3.21	12	1.61	1.14	--	0.10	0.79	4.552	0.159
		Descent	.206	.172	.668	.076	5.32	7.57	--	3.79	1.20	0.34	.05	1.01	9.307	.279
													Average		6.930	.219

(h) Configuration T13

M	011	Initial approach	0.287	0.175	0.329	0.067	6.75	6.84	27	3.63	1.80	--	0.07	1.09	9.671	0.343
		Descent	.479	.178	.300	.052	9.12	12.38	--	7.69	1.12	0.30	.02	1.63	15.463	.514
G	025	Initial approach	.155	.148	.246	.116	6.41	4.42	24	1.95	.95	--	.03	1.81	7.994	.244
		Descent	.375	.196	.163	.137	3.09	5.82	--	4.04	1.36	.10	.03	2.18	6.941	.445
K	152	Initial approach	.177	.166	.380	.085	8.13	5.31	13	2.37	1.67	--	.04	1.15	9.778	.257
		Descent	.231	.140	.436	.098	1.67	6.44	--	2.29	1.03	.18	.03	.80	6.701	.287
													Average		9.425	.348

(i) Configuration T15

M	042	Initial approach	0.120	0.106	0.108	0.020	5.59	3.51	45	1.68	1.20	--	0.13	0.58	6.626	0.161
		Descent	.210	.116	.373	.068	6.67	8.32	--	4.55	2.07	0.40	.29	3.26	11.151	.249
G	059	Initial approach	.172	.189	.068	.078	3.97	4.39	15	2.66	1.98	--	.13	.80	5.973	.267
		Descent	.306	.299	.159	.129	12.24	7.37	--	4.74	3.13	.45	.43	4.68	15.035	.447
K	238	Initial approach	.094	.204	.361	.070	6.89	2.86	53	.87	3.02	--	.13	.89	7.513	.235
		Descent	.219	.247	.295	.160	4.09	3.32	--	2.14	2.71	.10	.91	1.69	5.532	.367
													Average		8.638	.288

TABLE 3.- Continued.

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
(j) Configuration T16																
M	044	Initial approach	0.059	0.058	0.095	0.075	0.66	1.46	12	0.56	0.68	--	0.74	1.06	1.921	0.112
		Descent	.116	.169	.275	.117	2.43	3.82	--	1.40	3.04	0.22	.75	1.74	4.850	.236
K	241	Initial approach	.156	.121	.470	.058	5.30	2.42	18	2.10	.94	--	.34	3.26	6.676	.206
		Descent	.139	.205	.271	.181	1.21	2.76	--	1.62	2.47	.30	.45	2.07	3.656	.307
													Average		4.276	.215
(k) Configuration T17																
M	032	Initial approach	0.217	0.073	0.155	0.021	3.01	4.95	18	2.67	1.75	--	0.08	0.69	5.834	0.230
		Descent	.149	.114	.212	.055	1.85	4.24	--	1.55	.80	0.10	.01	1.76	4.950	.196
G	209	Initial approach	.116	.126	.316	.123	5.92	3.32	19	2.47	1.20	--	.05	1.26	6.903	.211
		Descent	.145	.129	.462	.104	8.09	5.14	--	2.21	.92	.11	.03	.91	9.628	.220
													Average		6.829	.214
(l) Configuration T18																
G	065	Initial approach	0.301	0.102	0.176	0.078	7.73	7.57	22	3.92	0.88	--	0.04	1.66	10.946	0.327
		Descent	.265	.160	.202	.071	5.05	5.95	--	4.02	1.03	0.12	.04	3.55	8.574	.318
K	244	Initial approach	.249	.160	.400	.106	7.85	8.75	43	3.84	1.85	--	.11	2.20	11.959	.314
		Descent	.314	.144	.430	.085	7.92	9.32	--	4.79	.86	.45	.07	2.23	12.432	.356
													Average		10.978	.329

TABLE 3.- Continued.

(m) Configuration T20

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
G	167	Initial approach	0.099	0.131	0.064	0.081	4.78	1.64	11	0.54	1.28	--	0.10	1.11	5.174	0.183
		Descent	.100	.142	.063	.199	1.25	1.56	--	.68	1.41	0.04	.43	2.16	2.943	.264
K	184	Initial approach	.084	.125	.323	.034	1.85	2.11	17	.52	1.26	--	.42	.70	2.892	.154
		Descent	.139	.283	.291	.078	2.21	3.06	--	.93	2.57	.24	.54	.86	3.871	.325
													Average		3.720	.232
(n) Configuration T21																
G	163	Initial approach	0.251	0.293	0.251	0.145	8.49	5.94	56	1.89	2.73	--	0.10	1.80	10.517	0.412
		Descent	.118	.250	.693	.178	3.58	5.78	--	.89	1.90	0.36	.29	3.33	7.571	.329
													Average		9.044	.370
(o) Configuration T22																
M	180	Initial approach	0.285	0.203	0.567	0.195	5.88	1.64	6	2.16	1.94	--	0.15	5.31	8.091	0.401
		Descent	.138	.254	.815	.032	3.26	5.71	--	.86	2.20	0.21	.07	2.81	7.150	.291
G	227	Initial approach	.152	.147	.403	.034	4.95	4.04	21	.91	1.01	--	.02	3.14	7.119	.214
		Descent	.056	.063	.203	.066	1.18	2.40	--	.34	.60	.14	.06	.75	2.778	.107
K	260	Initial approach	.108	.095	.356	.022	2.91	2.43	35	.77	.65	--	.02	.63	3.843	.146
		Descent	.087	.113	.583	.031	1.63	5.99	--	.93	.72	.22	.03	1.73	6.444	.146
													Average		5.904	.217

TABLE 3.- Continued.

(p) Configuration T23

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ε_{GS}	ε_{LOC}	β	P_{rss}	δ_{rss}
M	007	Initial approach	0.133	0.133	0.607	0.057	7.22	6.92	30	1.11	0.50	--	0.03	0.70	10.053	0.197
		Descent	.047	.272	.139	.051	1.49	2.87	--	.46	3.44	0.21	.15	.79	3.329	.281
K	145	Initial approach	.240	.106	.309	.018	8.97	4.03	20	1.98	1.35	--	.08	2.31	10.101	.263
		Descent	.104	.091	.557	.019	1.55	4.51	--	.70	.64	.14	.03	.90	4.853	.139
G	233	Initial approach	.248	.100	.576	.048	8.21	5.87	19	1.89	.63	--	.05	1.39	10.185	.272
		Descent	.125	.108	.754	.038	1.82	5.57	--	.89	.85	.20	.03	1.31	6.004	.170
													Average		7.421	.220

(q) Configuration T25

M	081	Initial approach	0.119	0.174	0.267	0.046	0.98	2.73	23	0.71	2.99	--	0.17	1.17	3.128	0.216
		Descent	.025	.192	.418	.037	1.09	3.89	--	1.21	3.04	0.10	.35	.89	4.137	.197
M	099	Initial approach	.013	.182	.056	.029	.77	1.95	6	.76	2.26	--	.18	.86	2.266	.185
		Descent	.008	.081	.326	.165	1.18	3.94	--	1.57	1.65	.16	.49	1.97	4.560	.184
K	268	Initial approach	.132	.229	.638	.041	2.36	2.30	7	1.92	3.30	--	.41	.77	3.384	.267
		Descent	.116	.141	.248	.119	3.33	4.88	--	2.09	2.25	.17	.71	1.49	6.093	.218
													Average		3.928	.211

(r) Configuration T26

G	089	Initial approach	0.154	0.214	0.206	0.129	10.60	3.88	59	2.58	2.34	--	0.45	1.74	11.421	0.294
		Descent	.143	.171	.223	.079	2.09	5.23	--	2.29	1.46	0.41	.25	1.40	5.804	.236
													Average		8.612	.265

TABLE 3.- Concluded.

(s) Configuration T27

Pilot	Run	Segment	Standard deviation												Composite S.D. index	
			δ_{ES}	δ_{AS}	δ_{CS}	δ_{RP}	V	$\dot{h}$	h	θ	ϕ	ϵ_{GS}	ϵ_{LOC}	β	P_{rss}	δ_{rss}
G	229	Initial approach	0.169	0.124	0.246	0.051	2.30	4.93	25	1.98	0.96	--	0.10	0.78	5.496	0.216
		Descent	.097	.147	.614	.060	2.13	6.09	--	1.63	1.17	0.26	.10	.85	6.507	.186
													Average		6.002	.201

(t) Configuration T28

G	073	Initial approach	0.121	0.074	0.541	0.166	8.04	4.05	23	1.75	1.34	--	0.09	1.76	9.173	0.218
		Descent	.016	.076	.236	.018	1.06	3.78	--	1.17	.50	0.12	.03	.78	4.003	.080
M	076	Initial approach	.230	.119	.624	.047	8.92	7.99	38	3.10	1.06	--	.10	1.63	12.086	.263
		Descent	.008	.086	.489	.049	1.12	4.43	--	1.34	.93	.14	.03	.95	4.667	.099
													Average		7.482	.165

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM 84258		

4. Title and Subtitle	5. Report Date
A Piloted Simulator Investigation of Stability and Control, Display, and Crew-Loading Requirements for Helicopter Instrument Approaches Part II - Supporting Data	September 1982
	6. Performing Organization Code A-9056

7. Author(s)	8. Performing Organization Report No.
J. V. Lebacqz, R. D. Forrest *, and R. M. Gerdes	

9. Performing Organization Name and Address	10. Work Unit No.
Ames Research Center, Moffett Field, CA 94035 * Federal Aviation Administration, Ames Research Center, Moffett Field, CA 94035	505-42-21
	11. Contract or Grant No.

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Aeronautics and Space Administration Washington, D.C. 20546	Technical Memorandum
	14. Sponsoring Agency Code

15. Supplementary Notes

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16. Abstract A ground-simulation experiment was conducted to investigate the influence and interaction of flight-control system, flight-director display, and crew-loading situation on helicopter flying qualities during terminal-area operations in instrument conditions. The experiment was conducted on the Flight Simulator for Advanced Aircraft at Ames Research Center. Six levels of control complexity, ranging from angular rate damping to velocity-augmented longitudinal and vertical axes, were implemented on a representative helicopter model. The six levels of augmentation were examined with display variations consisting of raw elevation and azimuth data only, and of raw data plus one-, two-, and three-cue flight directors. Crew-loading situations simulated for the control-display combinations were dual-pilot operation (representative auxiliary tasks of navigation, communications, and decision-making). Four pilots performed a total of 150 evaluations of combinations of these parameters for a representative microwave landing system (MLS) approach task. Pilot rating results indicated the existence of a control display trade-off for ratings of satisfactory, whereas ratings of adequate-but-unsatisfactory depended primarily on the control system; the control system required for ratings of adequate-but-unsatisfactory was clearly more complex for single-pilot operation than that for the dual pilot situation.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Helicopter Airworthiness Instrument flight	Unlimited Subject Category - 08

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	119	A06

*For sale by the National Technical Information Service, Springfield, Virginia 22161