INFORMATION AND DISPLAY REQUIREMENTS FOR AIRCRAFT TERRAIN FOLLOWING†

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SUMMARY

The objective of this work is to apply and validate the display design procedure for manned-vehicle systems, as premulgated in Refs [1]-[2], to a particular scenario of interest to the Air Force. The scenario chosen is that of zero-visibility high-speed terrain following ($V = 466$ ft/sec, $H = 200$ ft) with an A10 aircraft. We consider the longitudal (linearized) dynamics in our analysis. The variations in (commanded path over) terrain $\pi(t)$ are modeled as a 3rd - order random process.

The display design methodology is based on the Optimal Control Model of pilot response, and employs this model in various ways in different phases of the design process. The overall methodology, as shown functionally in Figure 1, indicates that the design process is intended as a precursor to manned simulation. It provides a rank-ordering of candidate displays through a three-level process.

1. *Information Level:* Here the OCM is applied to determine the relative importance of each system state to closed-loop performance, once a performance criterion is specified. For the candidate task, the performance criterion includes RMS terrain height errors $e(t) = \pi(t) - h(t)$ and RMS vertical acceleration. The OCM analysis indicates that error rate $\dot{e}(t)$ and terrain height acceleration $\ddot{\pi}(t)$ are the two most important pieces of information for the control task.

In addition to the above analysis, the OCM is also used to determine the optimal combination of system states to be used as a display for closed-loop control. This is the flight-director design process described in Ref [2]. For the candidate task the flight director is a linear combination of vehicle states and terrain shaping states.

2. *Display Level:* At this level of analysis the information requirements are integrated to propose several different realistic display systems. Human operator display and information processing limitations are included at this level, such as observation noise, attentional allocation, indifference thresholds, etc. For each candidate design, performance vs. workload curves are generated using the OCM. In the present case, the high utility of terrain

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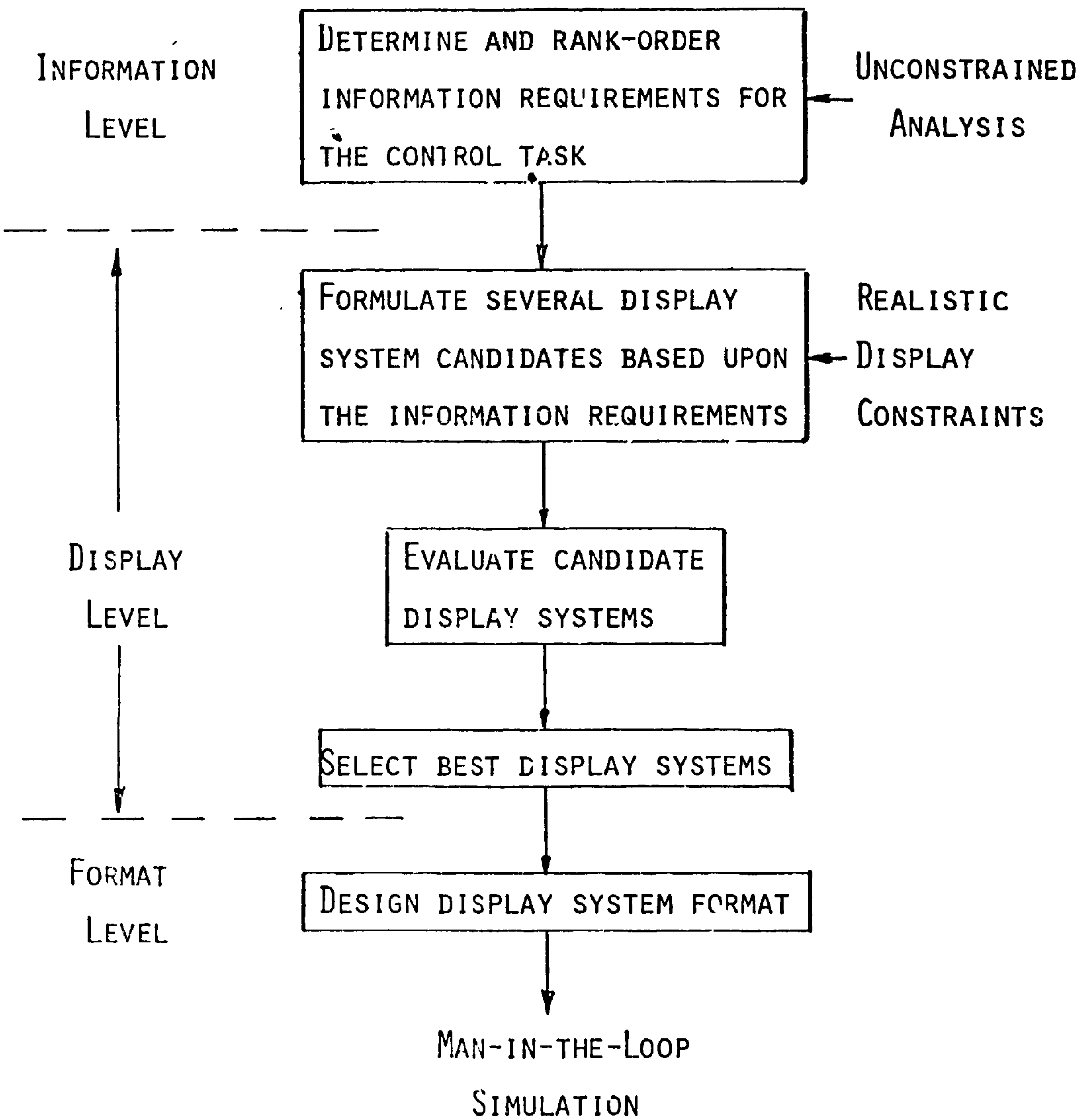

FIGURE 1 - OVERVIEW OF DISPLAY DESIGN METHODOLOGY

information (e.g. $\ddot{\pi}$) is included in a display via presentation/integration of the terrain height at a fixed distance/time ahead of the aircraft. Thus, displays are formulated to include realistically available measurements. Four candidate displays have been proposed via this procedure.

1. A tunnel display that indicates future desired flight path up to 3000' ahead of the aircraft.

2. A predictor-velocity vector display that indicates where the aircraft would be in $\simeq$ 4 sec, based on linear extrapolation, relative to the terrain height at that time.†

3. A combined tunnel plus velocity-vector display. This is basically the combination of 1) and 2).

4. The flight director display as designed at the information level.

In addition to the above synthetic display, the instrument panel is assumed to include: 1) Terrain height error e(t), 2) Radar altimeter, 3) pitch indicator and 4) G-meter.

The rank-ordering of the displays via the OCM indicates comparable levels of performance for displays 1-3, and much better performance using the flight director. Any of these displays yield significantly better performance than the non-synthetic display case, verifying the need for future flight path information.

3. *Format Level:* Here specific display formats are suggested for the presentation of specific display systems designed in level 2. Thus at this level the analytic display is translated into requirements for a physical display. Here we determine display layout, size and mode of presentation suitable for a man-in-the-loop simulation. The work at this level is largely an "art", but is guided by the sensitivities, attentional allocations, etc. that are generated by the OCM at the display level.

Man-in-the-loop experiments that evaluated the performance of the four candidate display systems were conducted at the CYBERLAB facility at the University of Connecticut. The experimental results tend to confirm the analytic rank-ordering of the candidate displays, and show a marked improvement in performance for the flight director design.

REFERENCES

1. Curry, R.E., D.L. Kleinman and W.C. Hoffman, "A Design Procedure for Control/Display Systems", Human Factors, Vol. 19, No. 5, Oct. 1977.

2. Hoffman, W.C., Kleinman, D.L. and Young, L.R., "Display/Control Requirements for Automated VTOL Aircraft", NASA CR-158905, Oct. 1976.

† This display is similar to the terrain box in use on the A10 HUD.