CREW WORKLOAD STRATEGIES IN ADVANCED COCKPITS

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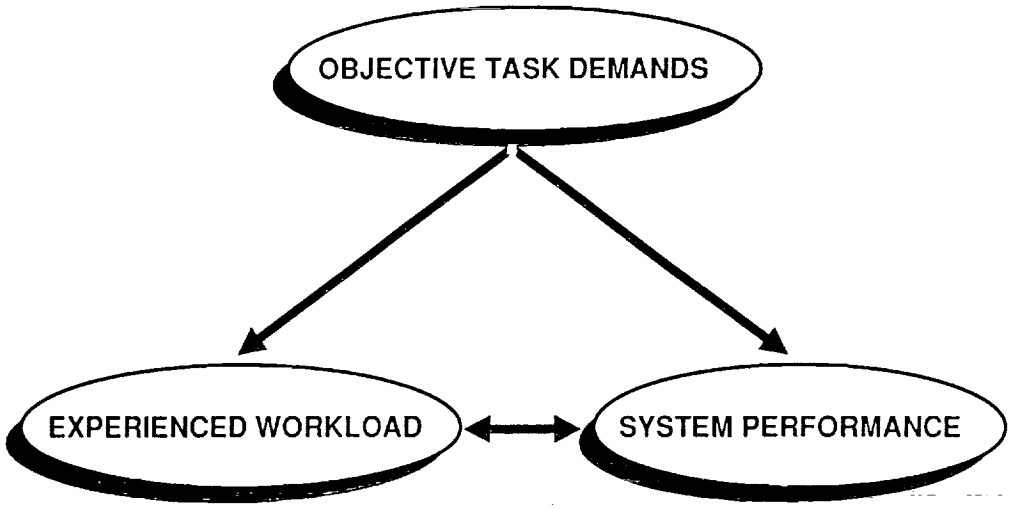
ABSTRACT

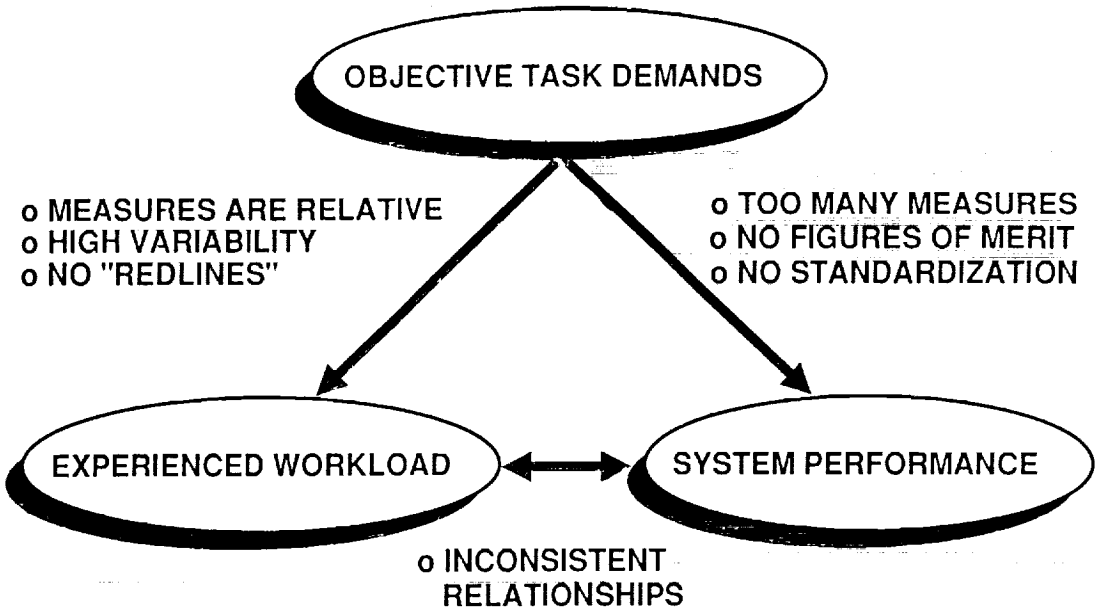
Many methods of measuring and predicting operator workload have been developed that provide useful information in the design, evaluation, and operation of complex systems and which aid in developing models of human attention and performance. However, the relationships between such measures, imposed task demands, and measures of performance remain complex and even contradictory. It appears that we have ignored an important factor: people do not passively translate task demands into performance. Rather, they actively manage their time, resources, and effort to achieve an acceptable level of performance while maintaining a comfortable level of workload. While such adaptive, creative, and strategic behaviors are the primary reason that human operators remain an essential component of all advanced man-machine systems, they also result in individual differences in the way people respond to the same task demands and inconsistent relationships among measures. Finally, we are able to measure workload and performance, but interpreting such measures remains difficult; it is still not clear how much workload is "too much" or "too little" nor the consequences of suboptimal workload on system performance and the mental, physical, and emotional well-being of the human operators. The rationale and philosophy of a program of research developed to address these issues will be reviewed and contrasted to traditional methods of defining, measuring, and predicting human operator workload.

PREVIOUS RESEARCH GOALS

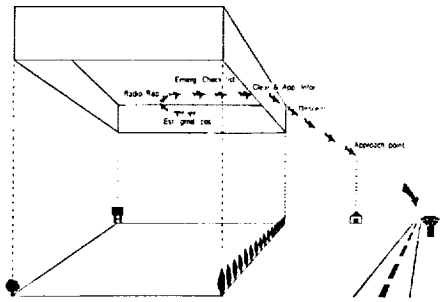
TO EXPLAIN, QUANTIFY, AND PREDICT RELATIONSHIPS AMONG:

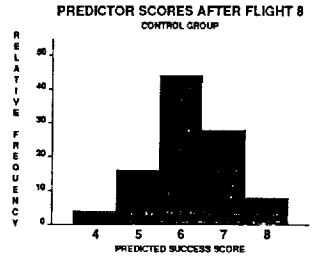


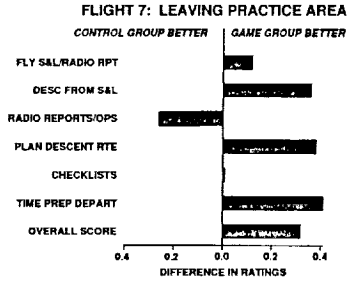
LESSONS LEARNED

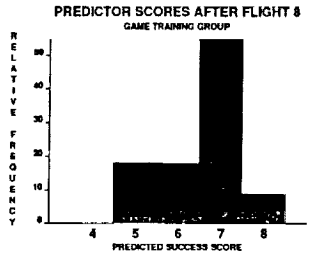


EFFECTIVENESS OF COMPUTER-GAME TRAINER IN IMPROVING WORKLOAD MANGEMENT SKILLS

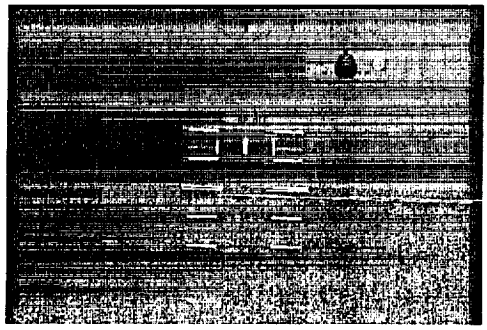


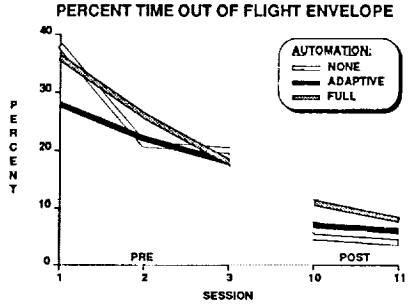


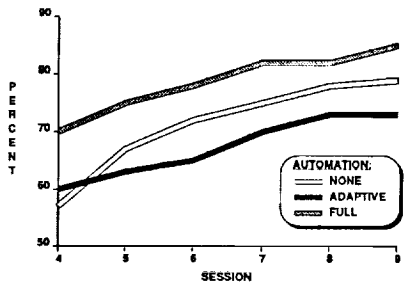




EFFECTIVENESS OF AUTOMATION IN RELEASING RESOURCES TO PERFORM OTHER TASKS



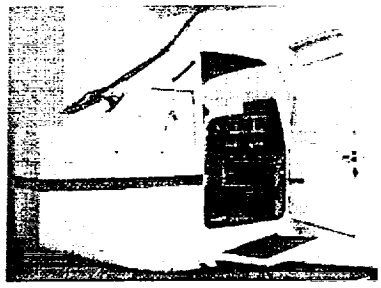


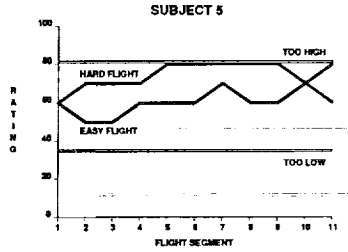


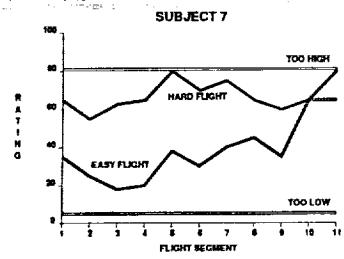
ELEMENT 4: METHODS OF IMPROVING STRATEGIES

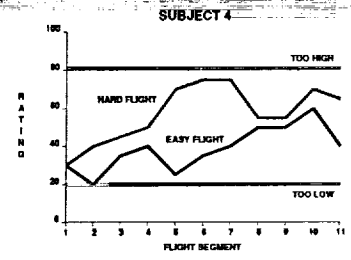
	FY89	FY90	FY91	FY92	FY93
MILESTONES:					
IDENTIFY OPTIMAL STRATEGIES FOR TYPICAL FLIGHT TASKS AND SITUATIONS					
DEVELOP TRAINING PROCEDURES TO IMPROVE PILOTS' MANAGEMENT OF TIME/RESOURCES, STRATEGY SHIFTS APPROPRIATE FOR STATE					
DEVELOP CONCEPTUAL DESIGNS FOR COMPUTER AIDS TO IMPROVE PILOTS' ABILITIES TO SELECT APPROPRIATE PLANS, STRATEGIES AND TACTICS					
TEST CONCEPTUAL DESIGNS FOR INFLIGHT ADAPTIVE SYSTEMS FOR DYNAMIC TASK ALLOCATION					

INDIVIDUAL DIFFERENCES IN SUBJECTIVE WORKLOAD "REDLINES"



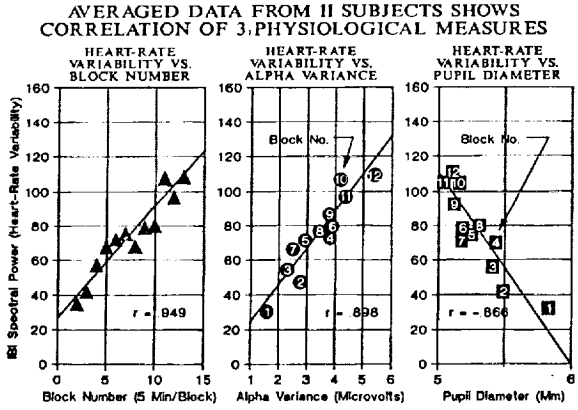


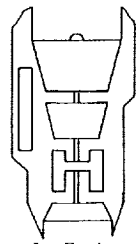




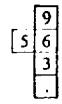
BOREDOM: PERFORMANCE/PHYSIOLOGICALCORRELATES

PHYSIOLOGICAL MEASURES



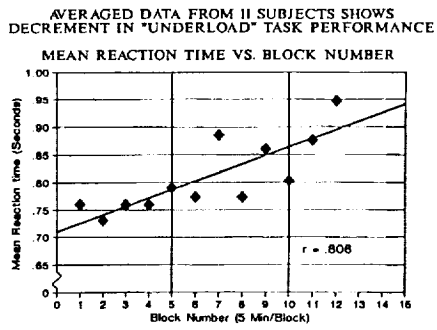


Jet Engine "Fault" Pictorial



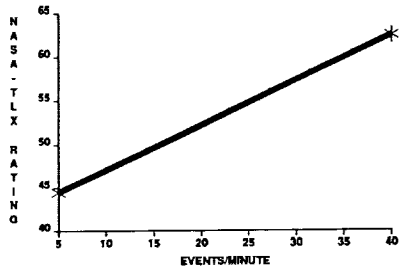
Computer Keypad Responses

TASK PERFORMANCE

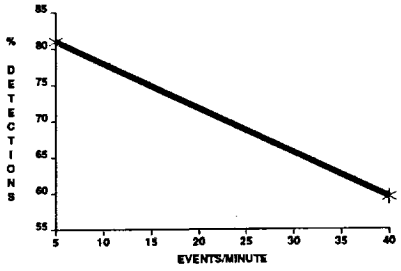


EFFECT OF BOREDOM ON PERFORMANCE , WORKLOAD

INFLUENCE OF BOREDOM ON RATED WORKLOAD



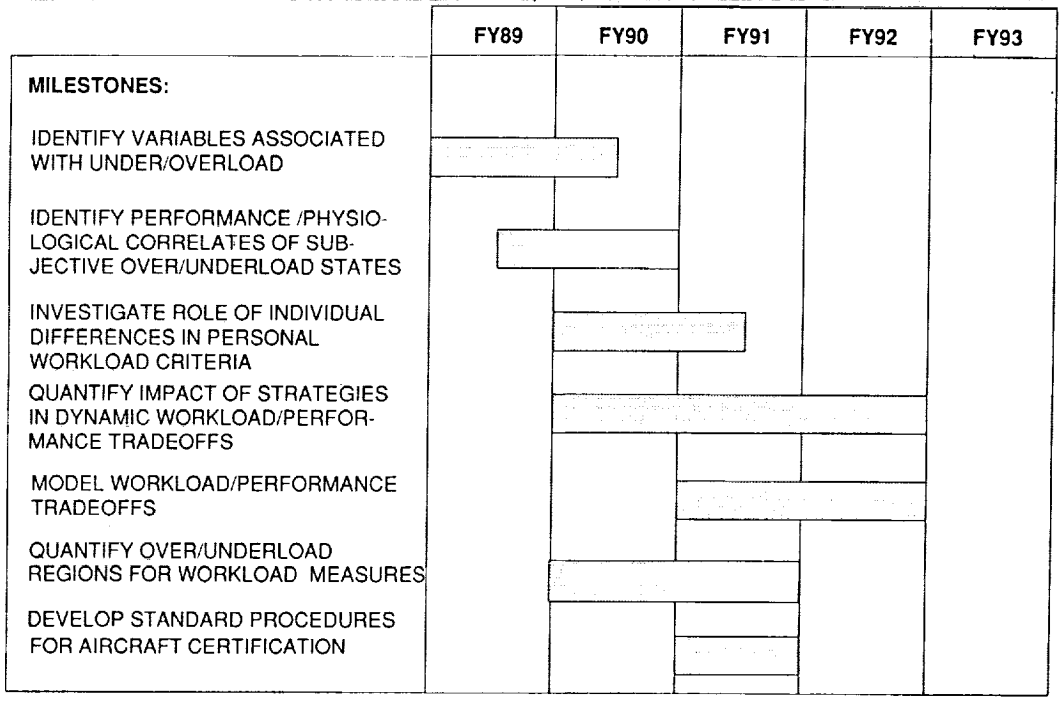
INFLUENCE OF BOREDOM ON PERFORMANCE



SYMPTOMS OF UNDER/OVERLOAD STATES

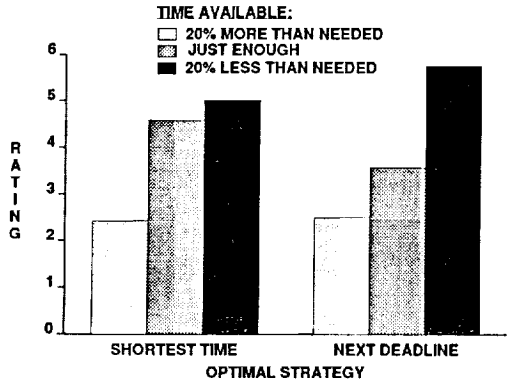
WORKLOAD		SUBJECTIVE EXPERIENCE:	PHYSIOLOGICAL INDICES:	STRATEGIES	PERFORMANCE:
UNACCEPTABLE (TOO HIGH)		OVER-WHELMED	SIGNIFICANT CHANGE	NONE	UNACCEP-TABLE
SUBOPTIMAL		STRESSED	SOME CHANGE	COMPEN-SATION: - SHED - DEFER	ACCEPTABLE
OPTIMAL		COMFORT-ABLE	"NORMAL"	MANAGE TASK DEMANDS	GOOD
SUBOPTIMAL		BORED	SOME CHANGE	COMPEN-SATION: TRIES TO MAINTAIN AROUSAL	ACCEPTABLE
UNACCEPTABLE (TOO LOW)		DROWSY	SIGNIFICANT CHANGE	UNPREPARED	POOR

ELEMENT 3: WORKLOAD "RED-LINES"

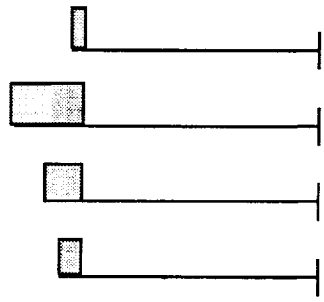


SCHEDULING THEORY MODELS OF WORKLOAD

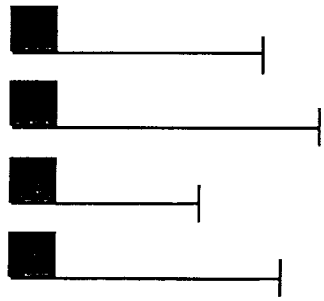
INFLUENCE OF STRATEGY ON RATED WORKLOAD



SHORTEST PROCESSING TIME

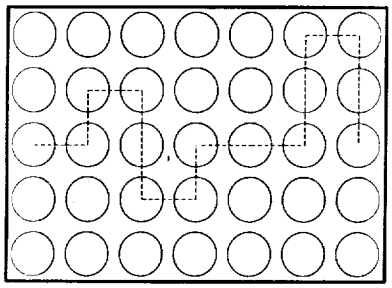


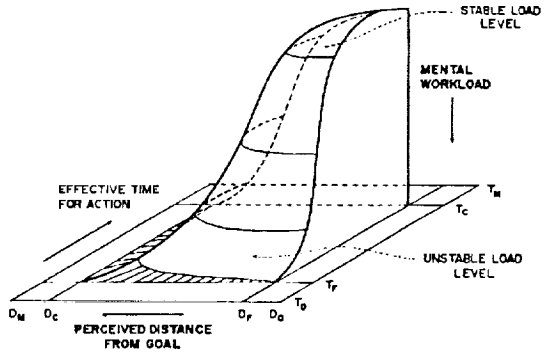
EARLIEST DUE DATE DISPLAY

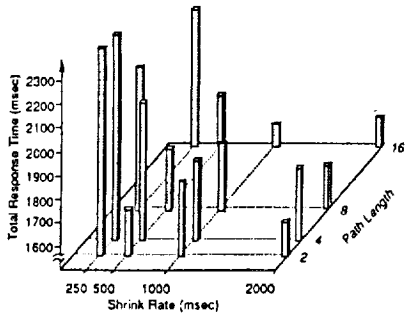


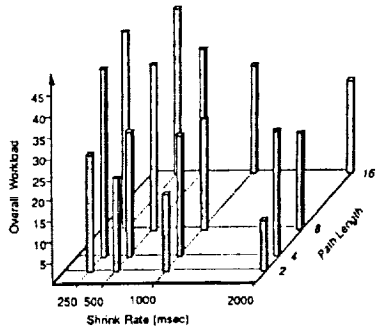
TEMPORAL DYNAMICS OF MENTAL WORKLOAD

TARGET SEQUENCE

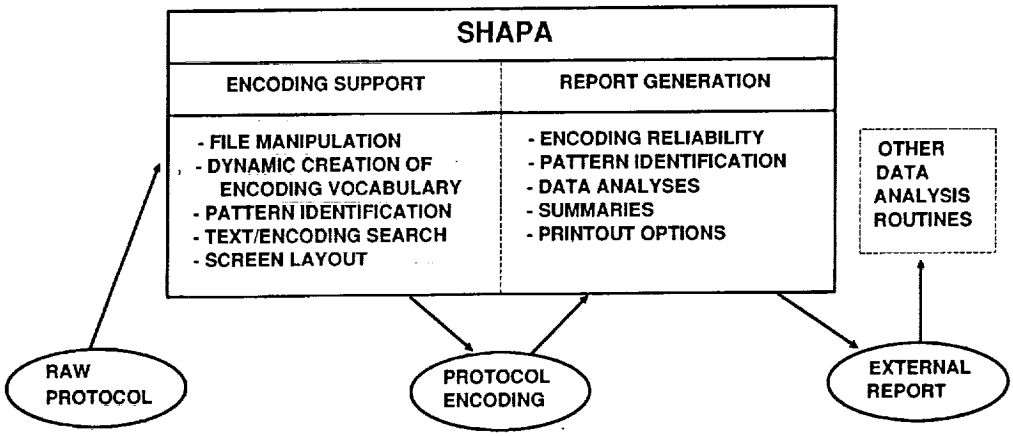








SHAPA: VERBAL/NONVERBAL PROTOCOL ANALYSIS TOOL



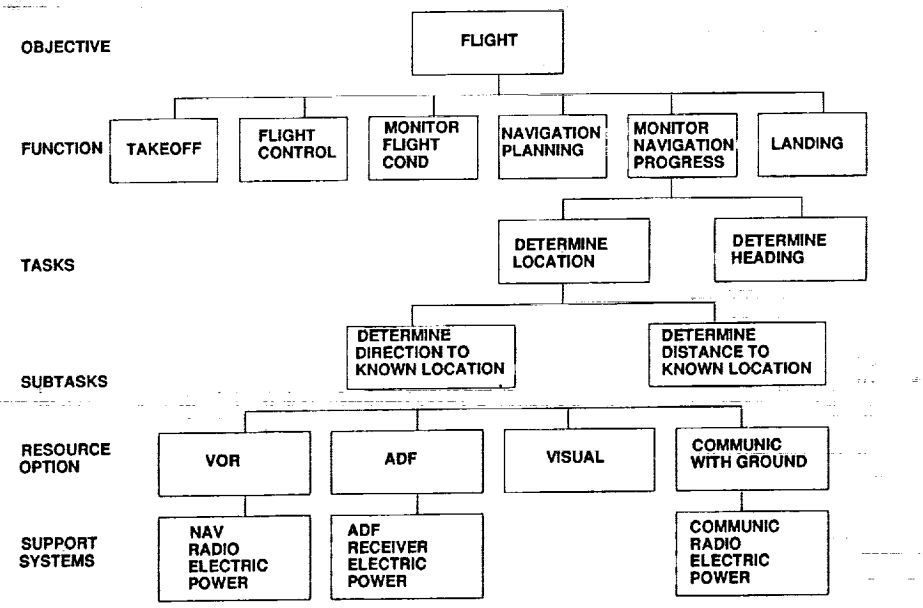
FEATURES:

- RUNS ON IBM-AT WITH EGA
- FULLY INTERACTIVE
- ENCODER DETERMINES ENCODING MODEL/THEORY
- FASTER ENCODING
- CHOICE OF DATA ANALYSIS TECHNIQUES
- DIRECT ENGAGEMENT WITH DATA

UNDER DEVELOPMENT: MacSHAPA

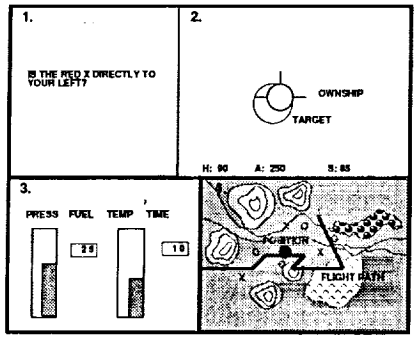
- MULTIPLE INTERACTING AGENTS
- MULTIPLE STREAMS OF VERBAL AND NON-VERBAL BEHAVIORS
- MULTIPLE ENCODERS/RESEARCHERS
- VISUALIZATION TOOLS

MODEL FOR CODING VERBAL PROTOCOLS TO ASSESS PILOT STRATEGIES

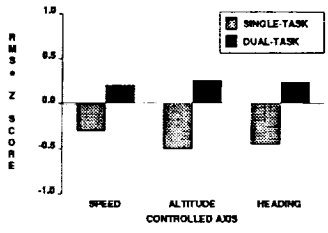


WORKLOAD /PERFORMANCE FOR COMPONENT TASKS

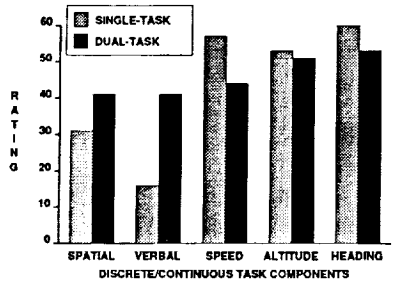
WINDOWS DISPLAY



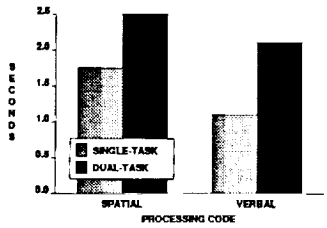
TRACKING ERROR FOR CONTROL TASK



RATED WORKLOAD OF TASK COMPONENTS

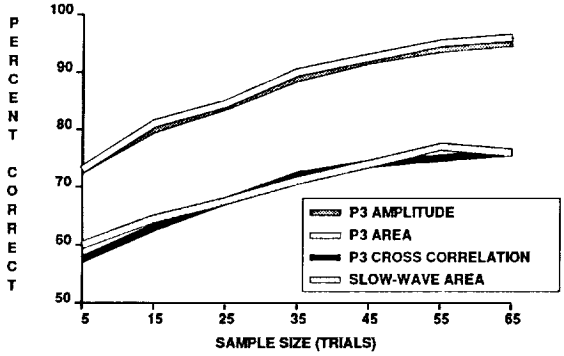


RESPONSE LATENCY FOR DISCRETE TASKS

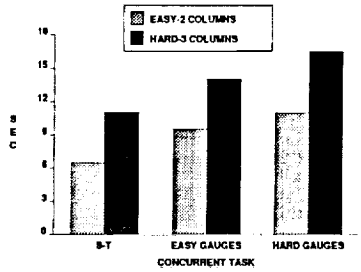


REAL-TIME MEASUREMENT OF MENTAL WORKLOAD

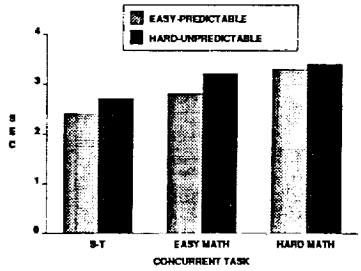
PERCENT CORRECTLY CLASSIFIED TRIALS: ERP MEASURES



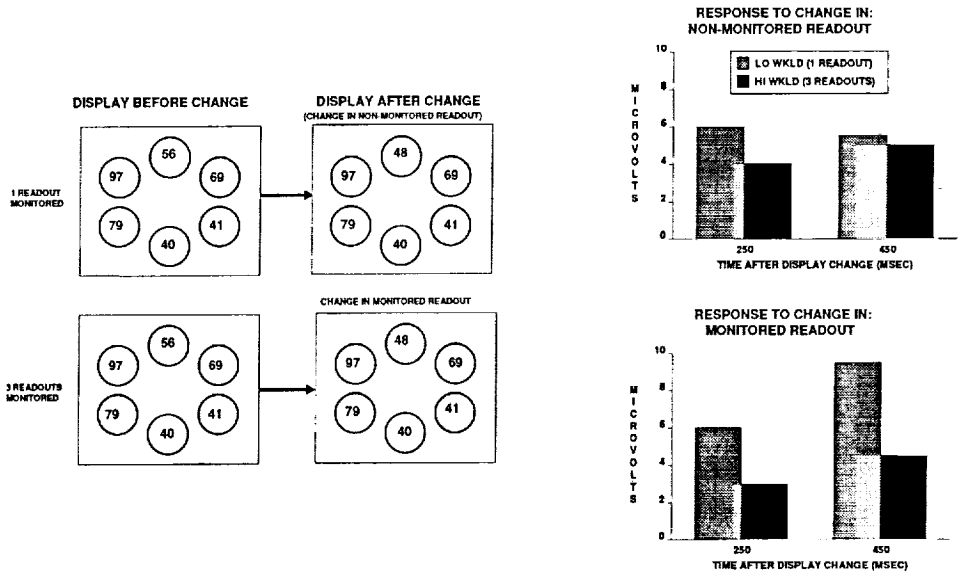
ARITHMETIC TASK: RESPONSE TIME



GAUGE MONITORING TASK: RESPONSE TIME



APPLICATION OF EVOKED POTENTIAL MEASURES IN COCKPIT SIMULATOR

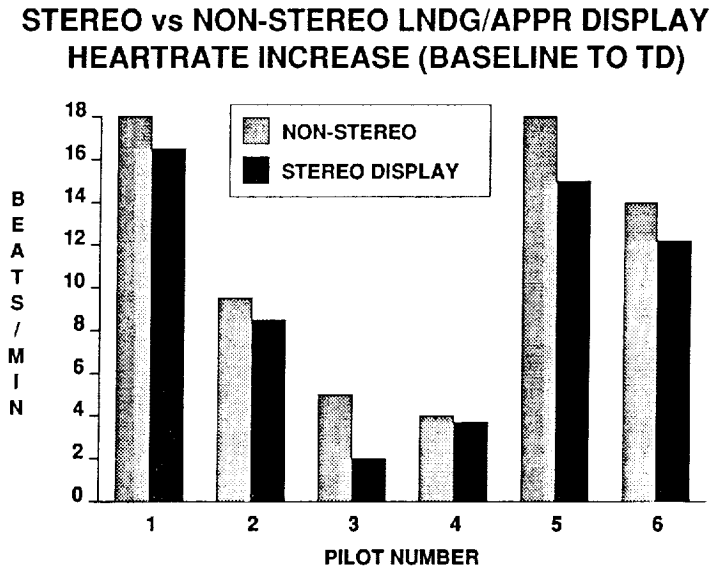


SENSITIVITY OF CARDIOVASCULAR MEASURES

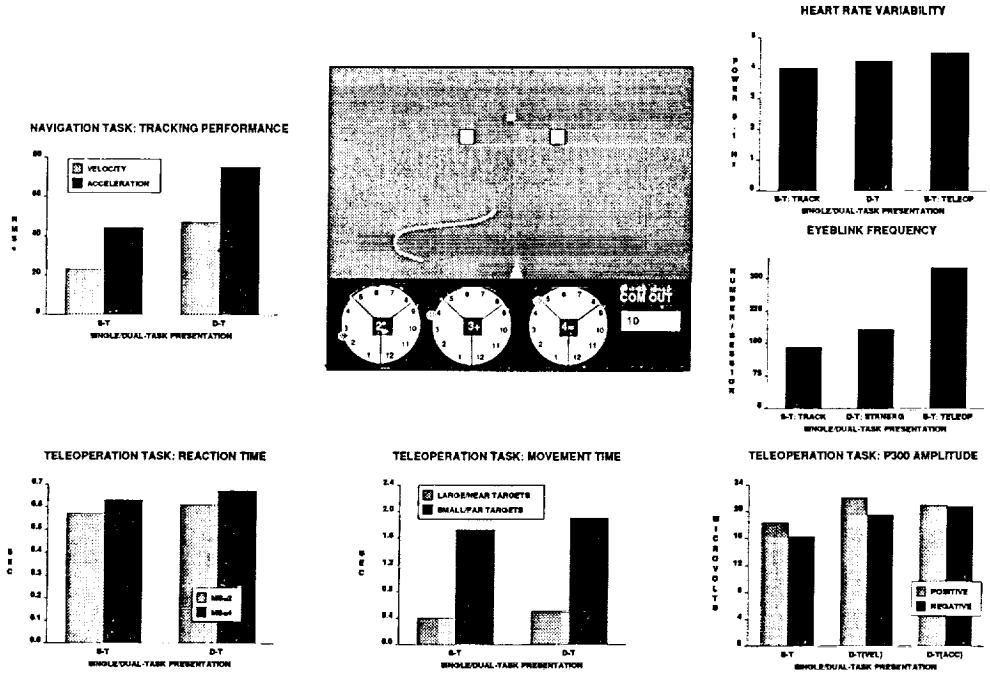
	FLIGHT PATH	CONTROL GUIDANCE	DISPLAY FORMAT	TIME ON TASK (UNDERLOAD)	TASK PACING
AVERAGE HEART RATE	+	+			
HEART RATE CHANGE	++	++	++		
HEART RATE VARIABILITY	+	+		++	+
BLOOD PRESURE COMPONENT HRV (0.1Hz)	+	+		++	

	NOT USEFUL
+	SHOWS TRENDS
++	STATISTICALLY SIGNIFICANT

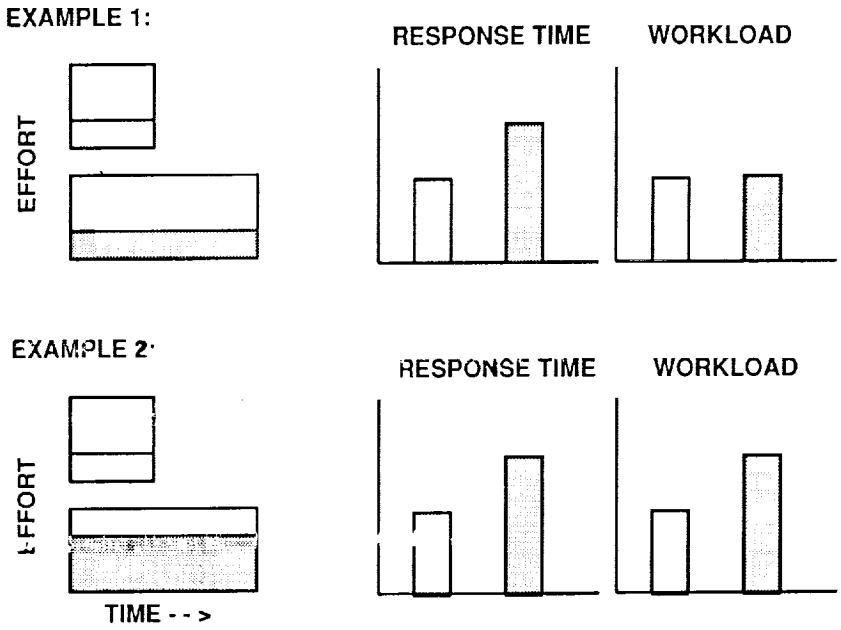
INFLUENCE OF DISPLAY DESIGN ON PILOT'S HEART RATE



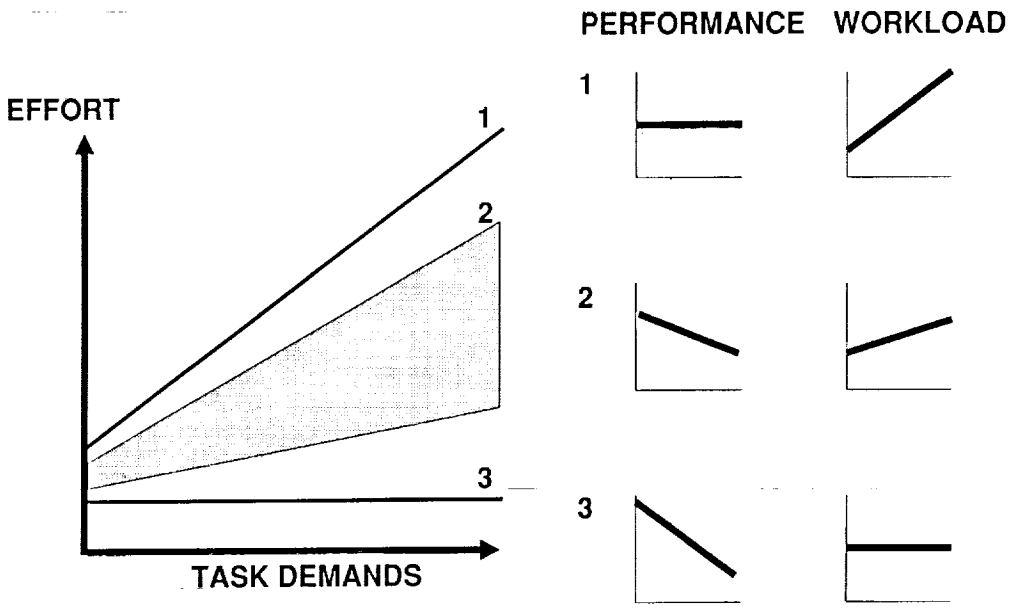
COMPARISON AMONG MEASURES



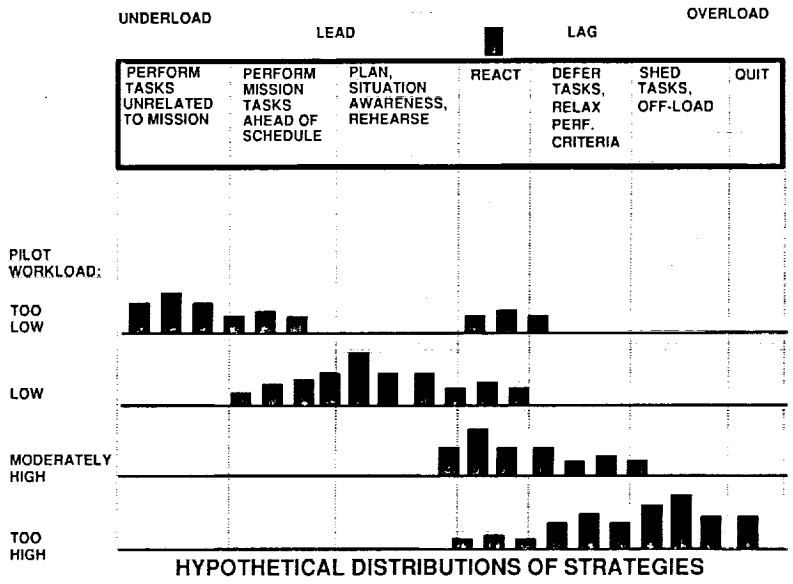
INFERENCES ABOUT "EFFORT" AND WORKLOAD CANNOT BE DRAWN FROM MEASURES OF REACTION TIME



HYPOTHETICAL RELATIONSHIPS BETWEEN TASK DEMANDS, EFFORT, MEASURES OF PERFORMANCE, AND WORKLOAD

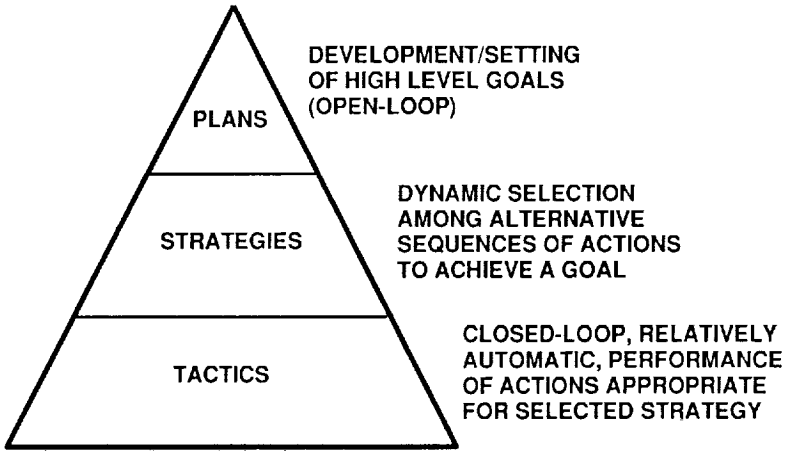


PILOTS ADOPT DIFFERENT STRATEGIES WITHIN A FLIGHT

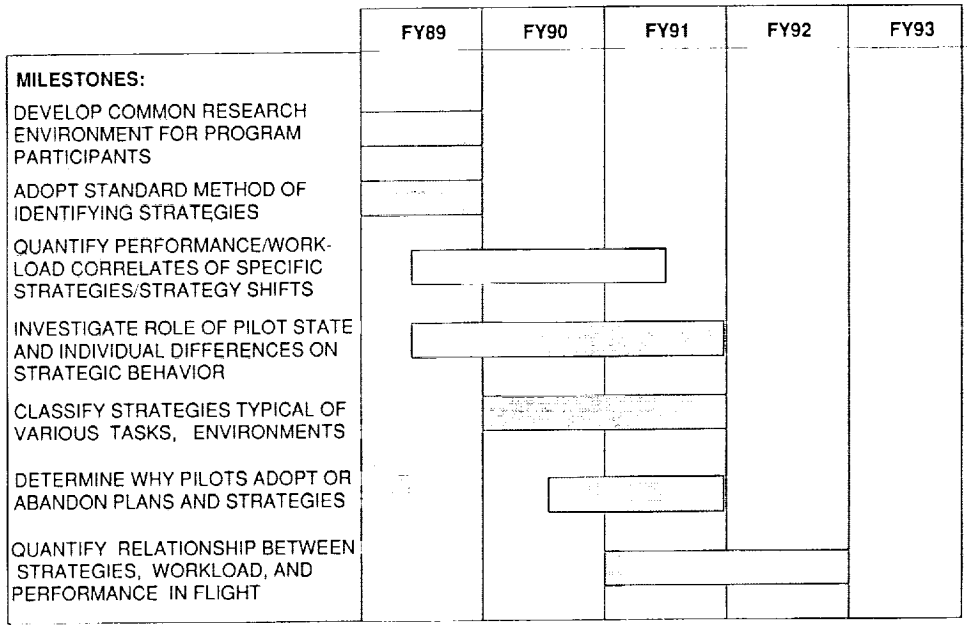


HYPOTHETICAL DISTRIBUTIONS OF STRATEGIES

CHARACTERISTICS OF STRATEGIC BEHAVIORS



ELEMENT 2: STRATEGIC BEHAVIOR



FIGURES OF MERIT - II

GOAL:

IDENTIFY A PARSIMONIOUS SET OF VARIABLES WHICH, IN COMBINATION, ARE DESCRIPTIVE OF THE INFLUENCE OF THE PILOT/VEHICLE INTERFACE DESIGN AND PILOT'S INTENT ON SYSTEM PERFORMANCE

APPROACH:

- **SELECT 50 VARIABLES FROM THOSE ALREADY AVAILABLE**
- **MONITOR PERFORMANCE OF NOVICE AND EXPERT PILOTS IN AFTI F-16 DURING:**
  - **AIR-TO-AIR MISSION**
  - **TERRAIN-FOLOWING MISSION**
- **MEASURE PILOT WORKLOAD USING SWAT**
- **SELECT PARSIMONIOUS SET OF VARIABLES USING MULTI-DIMENSIONAL SCALING, CLUSTER ANALYSIS, ETC**
  - **IDENTIFY REDUNDANT MEASURES**
  - **IDENTIFY MEASURES THAT PROVIDE UNIQUE INFORMATION**
  - **COMBINE SOME MEASURES TO CHARACTERIZE A PARTICULAR ASPECT OF PERFORMANCE**

FIGURES OF MERIT - I

GOAL:

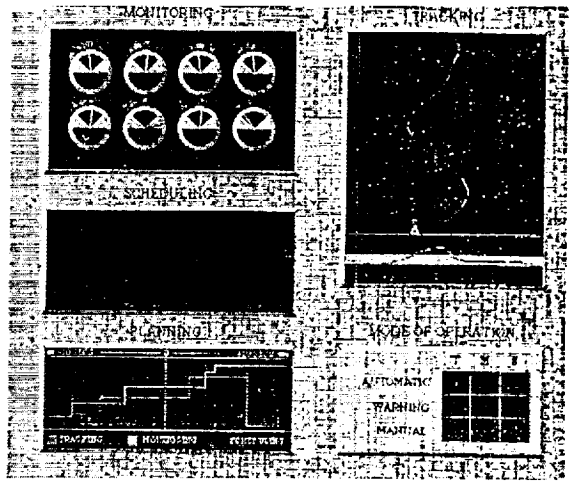
DEVELOP COMPOSITE FIGURE OF MERIT FOR PERFORMANCE

APPROACH:

- EXPERIMENTAL TASK (SCORE):
  - 10-MIN TRIALS
  - 2nd-ORDER, 1-AXIS PURSUIT TRACKING
  - MONITOR 8 DIALS
  - ONLINE SUBTASK PERFORMANCE FEEDBACK
- FIGURE OF MERIT
  - EQUALLY WEIGHTED AVERAGE OF:
    - TRACKING (% MAX ERROR; 1-10)
    - MONITORING (% MAX ERROR; 1-10)
  - SELF EVALUATION (ONCE PER MIN)

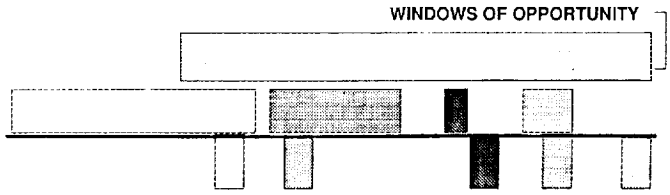
RESULTS:

- Ss FOCUSED ON TRACKING (BASED ON PERFORMANCE STRATEGY, SELF RATING)
- EQUAL WEIGHTING INAPPROPRIATE



FIGURES OF MERIT ARE NEEDED THAT CAPTURE THE QUALITY OF OVERALL PERFORMANCE

DISCRETE TASKS



MEASURES:
TIMELINESS
CORRECTNESS
TIME-SHARING STRATEGIES

CONTINUOUS TASKS

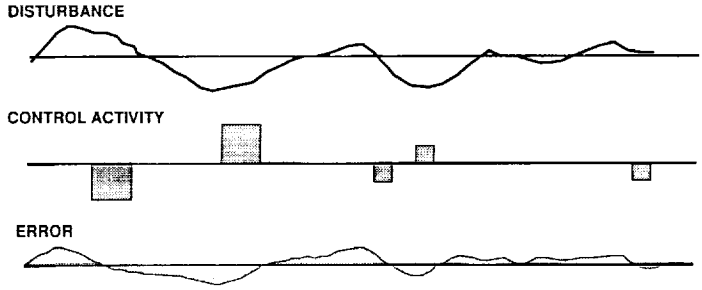
MEASURES:
% TIME IN ACCEP-TABLE RANGE

RANGE OF ACCEP-TABLE DEVIATIONS

TRADITIONAL MEASURES LOSE THEIR MEANING IF OPERATORS DO NOT TRY TO RESPOND: (1) IMMEDIATELY AND (2) PERFECTLY

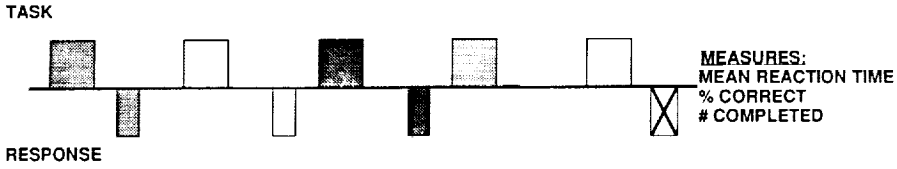
DISCRETE TASKS

CONTINUOUS TASKS

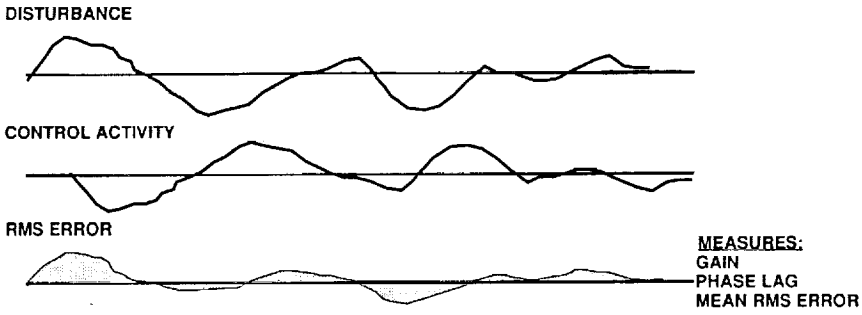


TRADITIONAL MEASURES OF PERFORMANCE

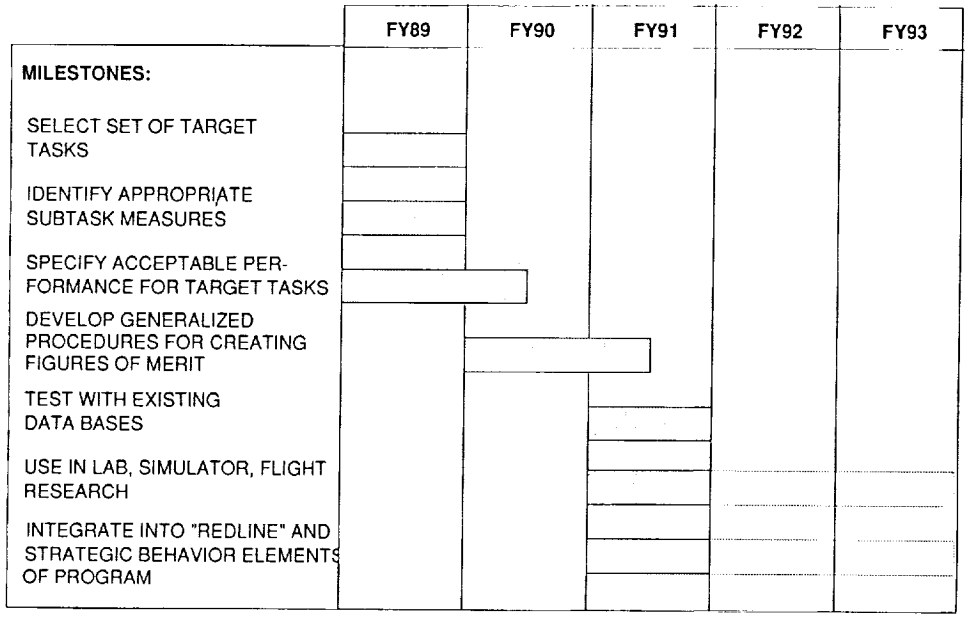
DISCRETE TASKS:



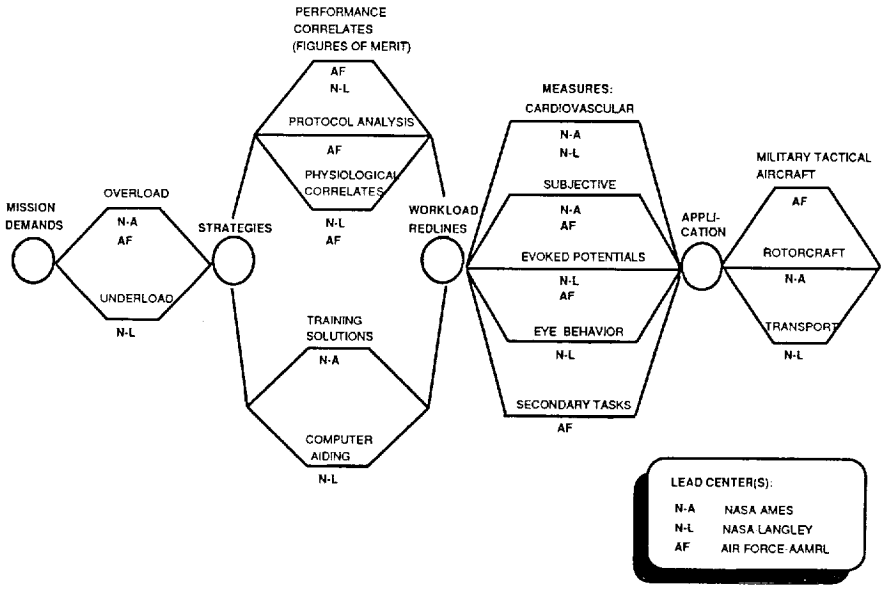
CONTINUOUS TASKS:



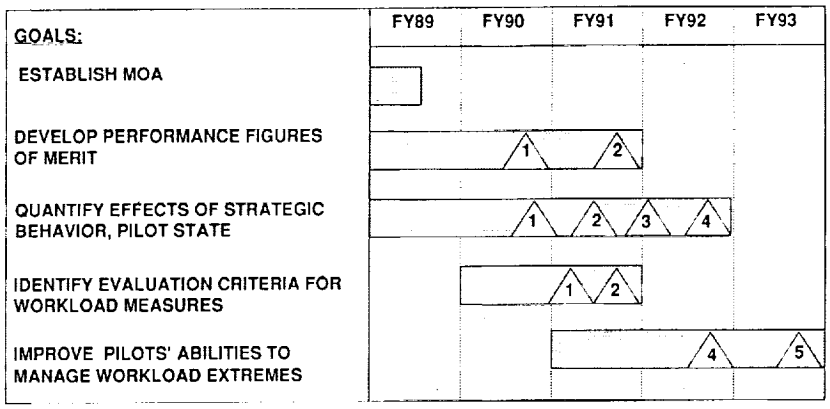
ELEMENT 1: FIGURES OF MERIT (FoM)



PROGRAM ORGANIZATION: LEAD ROLES



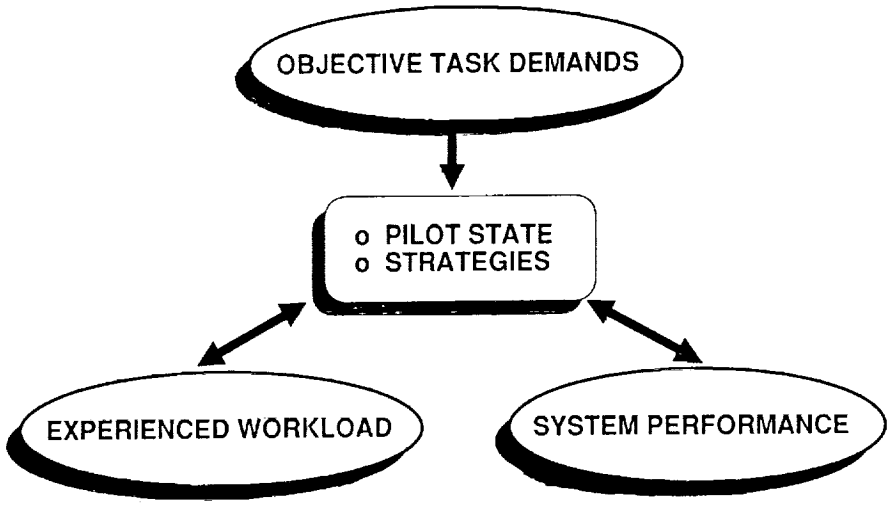
PROGRAM ELEMENTS/MAJOR MILESTONES



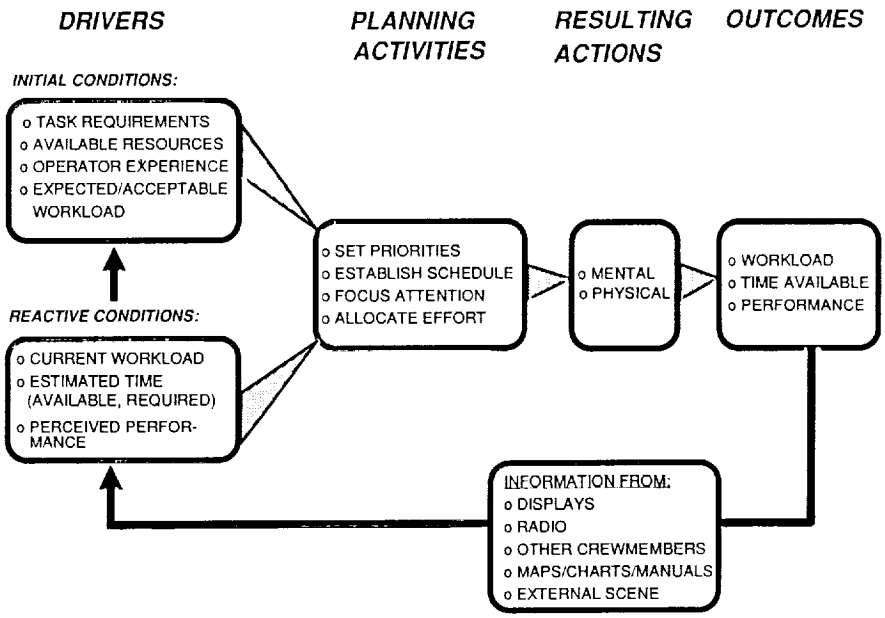
PRODUCTS:

1. PREDICTIVE TOOLS FOR SYSTEM DESIGNERS
2. STANDARD EVALUATION PROCEDURES FOR AIRCRAFT CERTIFICATION
3. IMPROVED THEORETICAL MODEL OF WORKLOAD
4. WORKLOAD-MANAGEMENT TRAINING CONCEPTS
5. ADAPTIVE COMPUTER AIDS TO IMPROVE TASK ALLOCATION

PROPOSED EXPLANATION



PROPOSED DYNAMIC CONCEPT OF WORKLOAD



CURRENT CONCEPTUALIZATIONS OF WORKLOAD GENERALLY IGNORE THE DYNAMIC, ADAPTIVE, CREATIVE BEHAVIOR OF HUMAN OPERATORS