Human Control of Systems

- Tracking Tasks
- Human Performance Considerations
- Measuring Tracking & Controlling Performance
- System Behaviors
- Representing System Behaviors

Tracking/Controlling Tasks

Attributes:
- External input/command signal defines operator response which equals manipulating control mechanism.
- Control mechanism generates an output.
- Tracking Error = Input – Output (operator requirement = null error signal)

Main Elements:
- Human Operator
- Intrinsic Behavior
- Representation of System’s State
- Operator’s Response Controls

Input & Output Signals

Inputs (Targets and Courses)
- Constant
  - Achieve and main constant heading/velocity
- Variable
  - Follow curving path
  - Chase a maneuvering butterfly

Waveforms – Ramp, Step, Sinusoidal

Input Waveforms

Examples:
- Ramp: Constant Rate of Change
- Step: Discrete Change in Value
- Sinusoidal: Cyclic Changes

Outputs
- Results indicated by display (cursor).
- Results manifested in system behavior.
## Tracking/Controlling Tasks

Steps in Psychomotor Performance:
- Plan
- Initiate
- Control
- End
- Check

## Manual Control Performance

### Information Processing Limits
- Processing Time
- Bandwidth
- Anticipation
- Psychological Refractory Period Limitation

## Limitations

- Processing Time (150 – 500 ms)
- Bandwidth (Maximum 2 corrections per second)
- Anticipation – Required due to system time lags
- Psychological Refractory Period Limitation (Minimum 300 ms between response and next stimulus)

## Measuring Performance

- Errors in Position
- Frequency Analysis of Responses
- Errors in Time and Phase

## Errors in Position

- Constant Position Error (Mean Error)
- Variable Error (Standard Deviation of the Error)
- Average Absolute Error (Modulus Mean Error)
- Root Mean Squared Error

## Pursuit & Compensatory Displays

- **Pursuit** - Displays both target & cursor movements
  - Task = Align moving cursor with moving target
  - Operator can observe changes in both target and cursor and determine which contributes to the error.

- **Compensatory** - Displays only one moving element
  - Task = Align cursor with target
  - Operator observes only absolute error and cannot determine which element movement contributes to the error.
System Control Orders

- Position (Zero-Order) Control
- Rate (First-Order) Control
- Acceleration (Second-Order) Control
- Higher-Order Controls

Factors Influencing Tracking Performance

- Preview of Track Ahead
- Type of Display (Pursuit / Compensatory)
- Time Lags in Tracking
- Specificity of Displayed Error
- Paced vs. Self-Paced Tracking

Procedures Facilitating Tracking Performance

- Aiding
- Predictor Displays
- Quickening

System Behavior

- Speed/Accuracy Trade-Offs
  - Fitts Law Index of Movement Difficulty (ID)
    \[ ID(\text{bits}) = \log_2(2A/W) \]
    - \( A \) = Amplitude of intended movement
    - \( W \) = Width of target area
  - Movement Time (MT)
    \[ MT(\text{seconds}) = km + ID / cm \]
    - \( km \) = Delay Constant (Hands = 0.177 second)
    - \( cm \) = Information Handling Capacity (0.1 bps)

Control Responsiveness

- Control-Response (C/R) Ratio = Movement of Control Device / Movement of System Response
  Note: Previously referred to as Control-Display (C/D) Ratio
  - Low C/R = High Sensitivity
  (Small Movement --- Large Response)
  - Note: Reciprocal of C/R = System Gain