

Comparing Visual Cues Necessary for Inner- and Outer-Loop Control

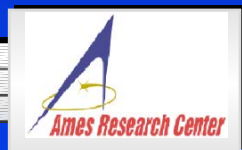
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Outline

- **Introduction**
- **Control Task Characterization**
- **Perceptual Requirements**
- **Empirical Findings**
 - **Attitude/Attitude Rates**
 - **Position/Velocity**
 - **Vehicle Dynamics**
 - **Motion Perception**
- **Implications for Display Design**
- **Conclusions**

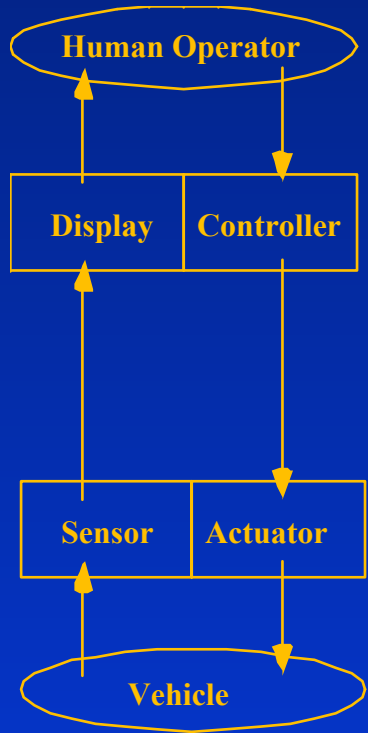
Introduction

- **Level of human supervision varies along continuum from fully manual to fully automatic**
- **Information requirements a function of this control regime**
- **Requirements can also vary as a function of vehicle dynamics and/or flight phase (i.e., landing vs. cruise)**

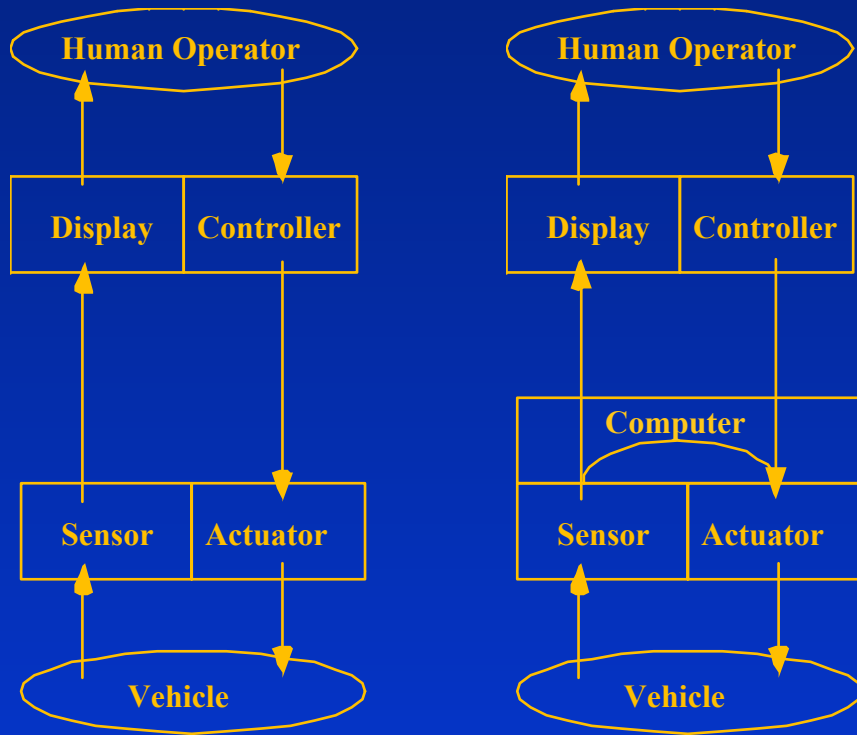
Control Task Characterization



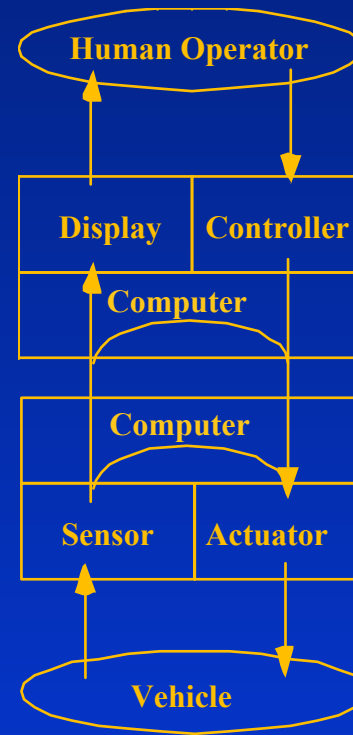
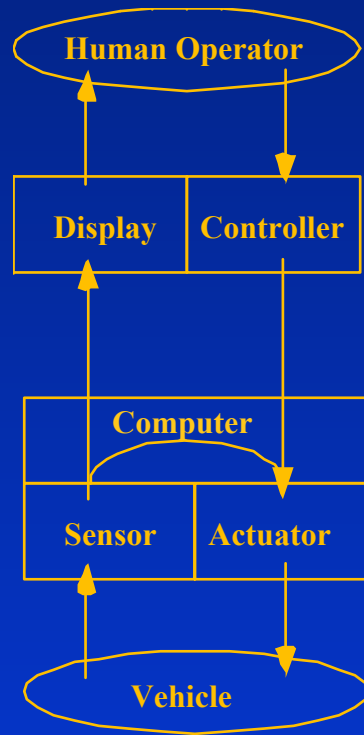
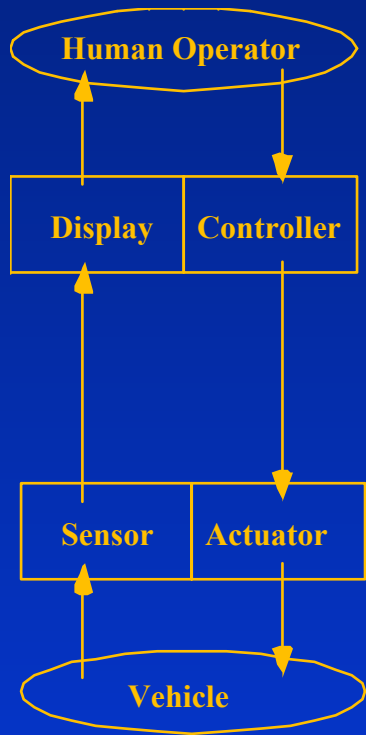
Control Task Characterization



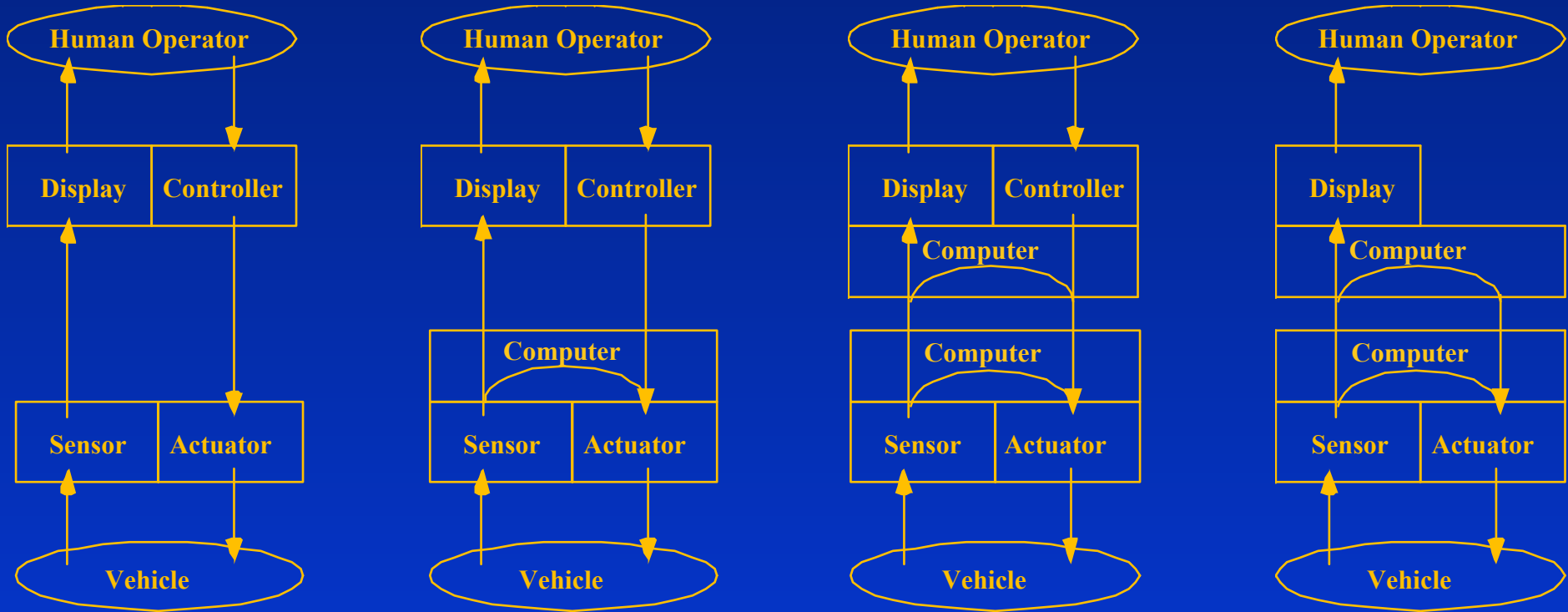
Control Task Characterization



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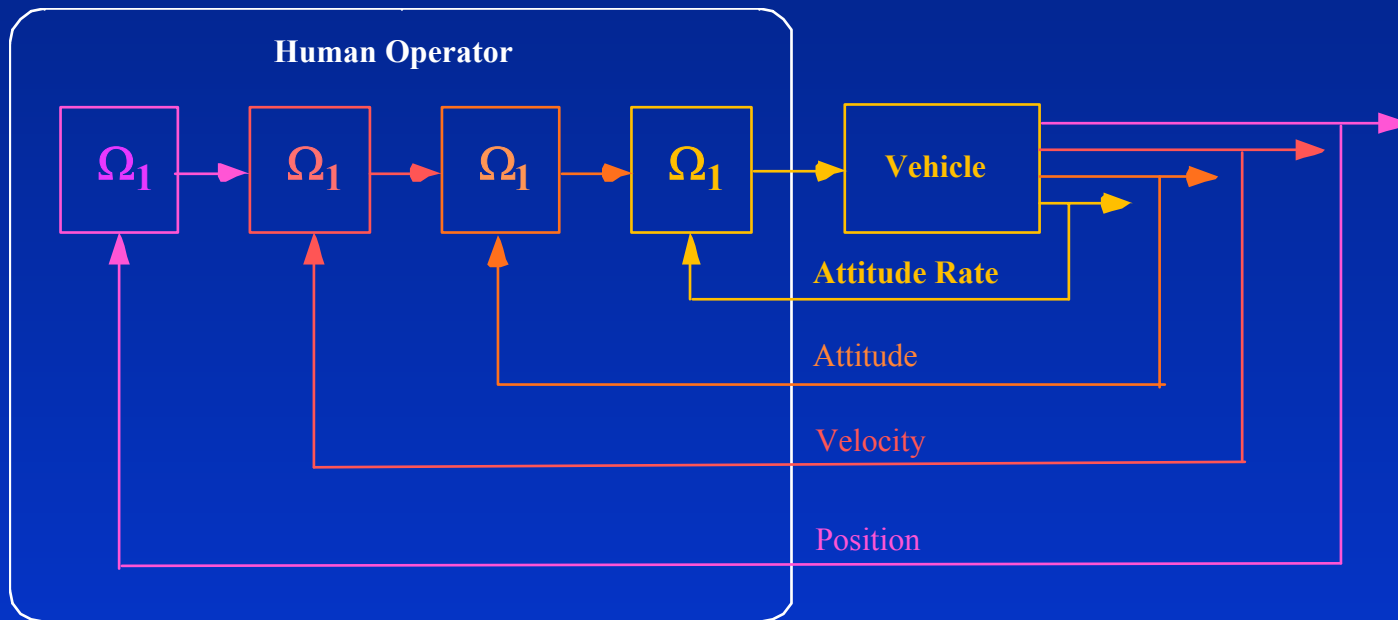


Manual

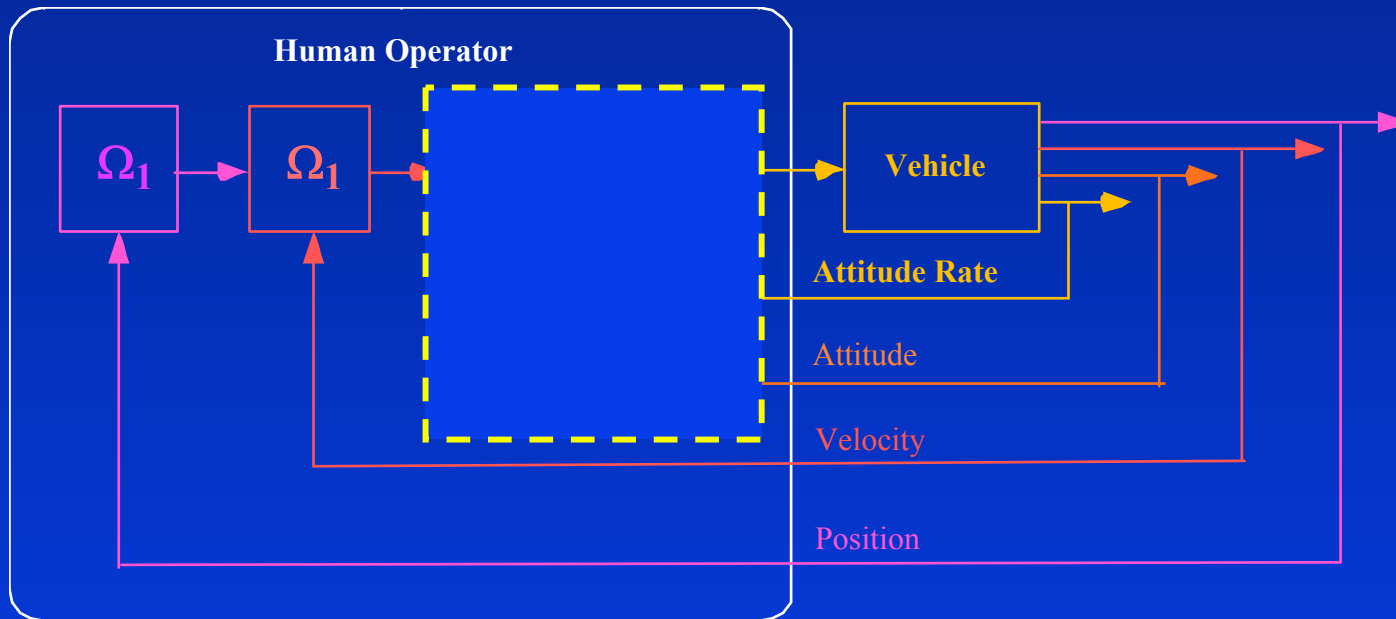
Supervisory

Automatic

Multi-loop Control Task

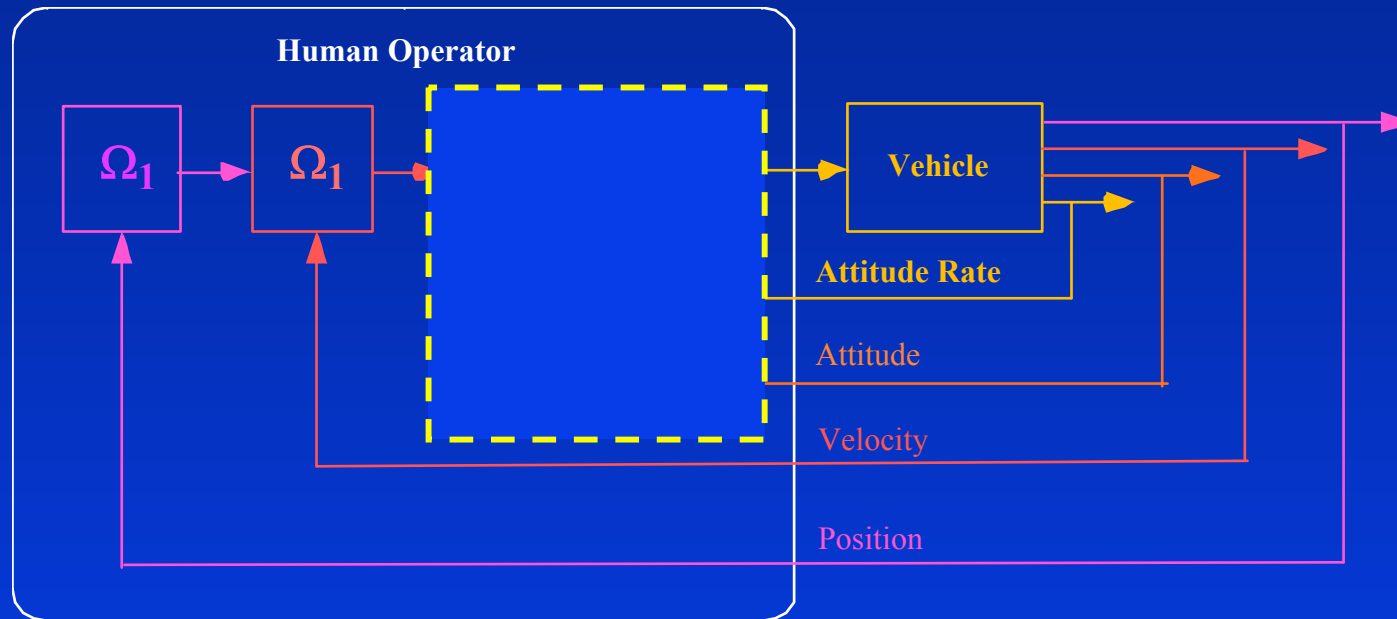


Perceptual Requirements



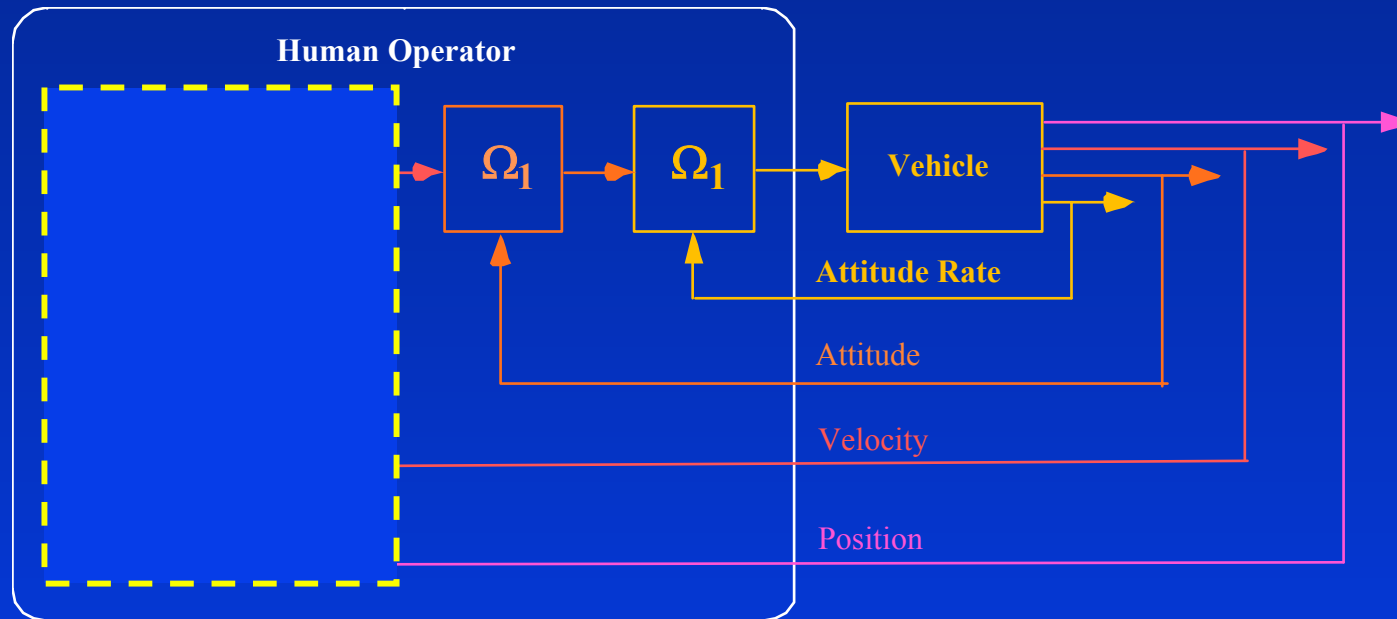
Perceptual Requirements

- Inner Loop - attitude and attitude rates



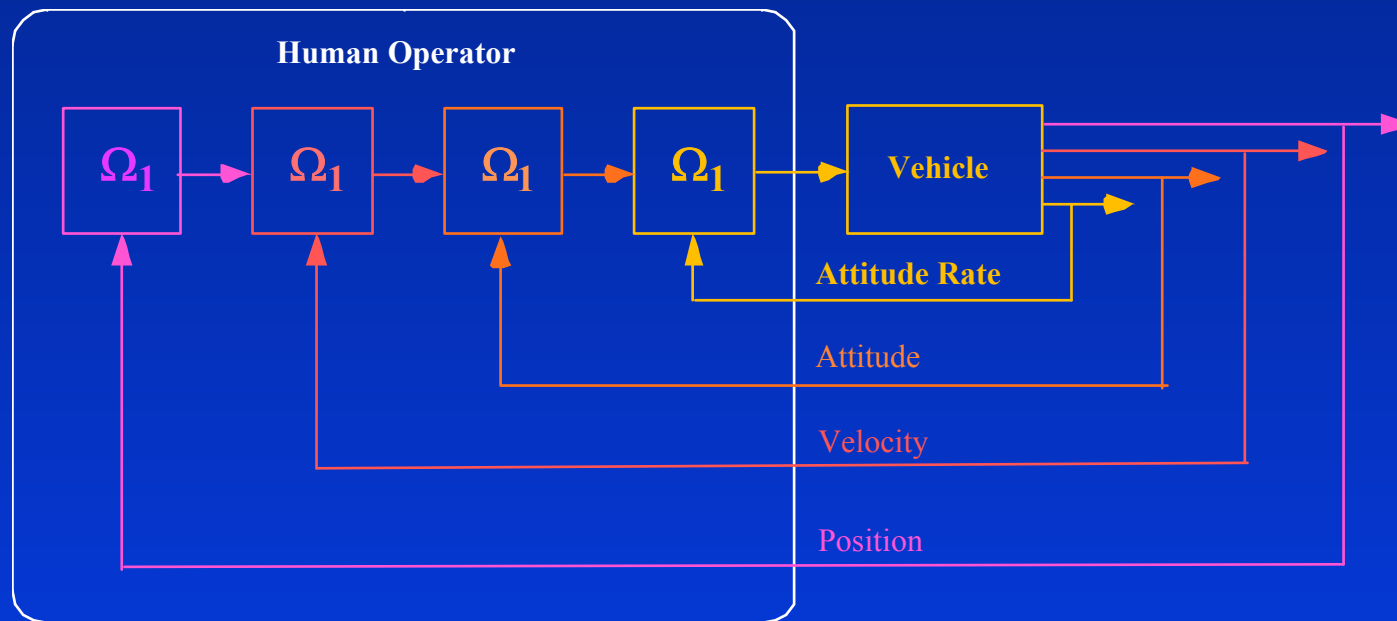
Perceptual Requirements

- Inner Loop - attitude and attitude rates
- **Outer Loop - velocity and position**



Perceptual Requirements

- Inner Loop - attitude and attitude rates
- Outer Loop - velocity and position

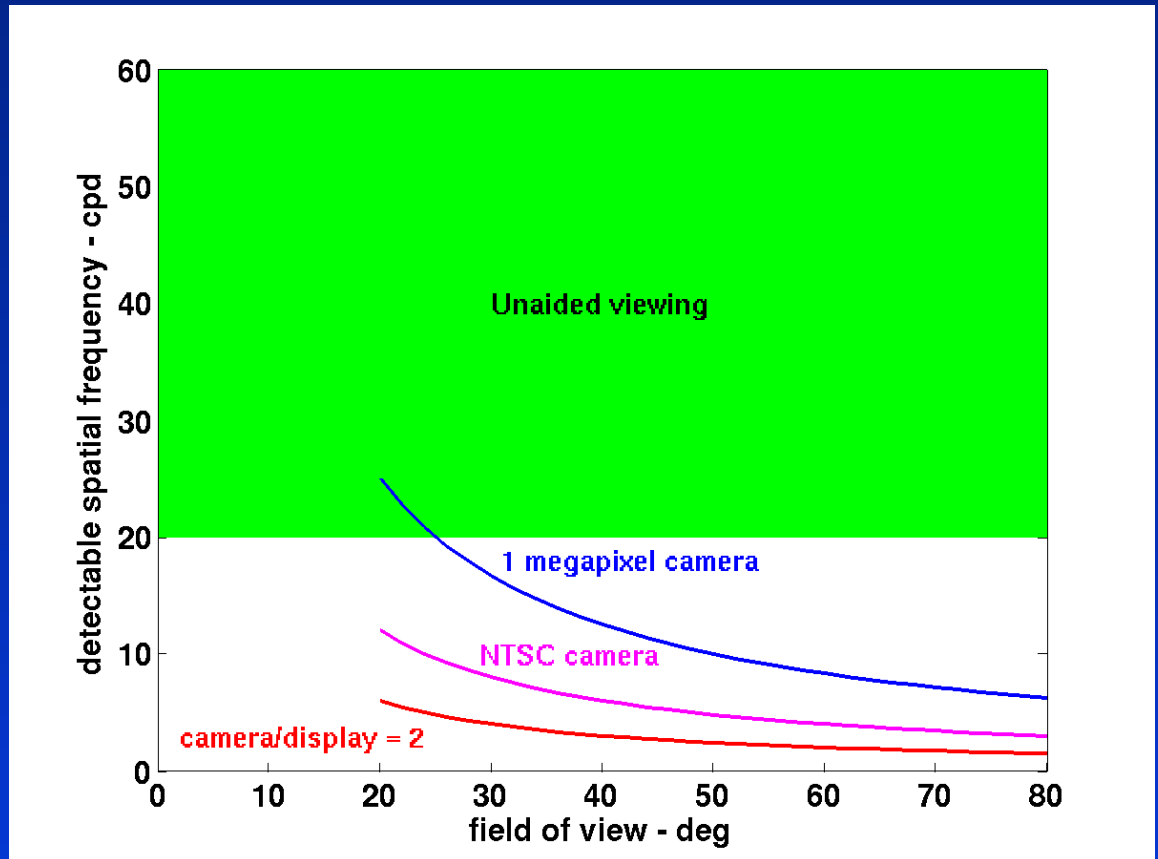


Empirical Findings

- **Attitude/Attitude Rates**
- **Position/Velocity**
- **Vehicle Dynamics**
- **Motion Perception**

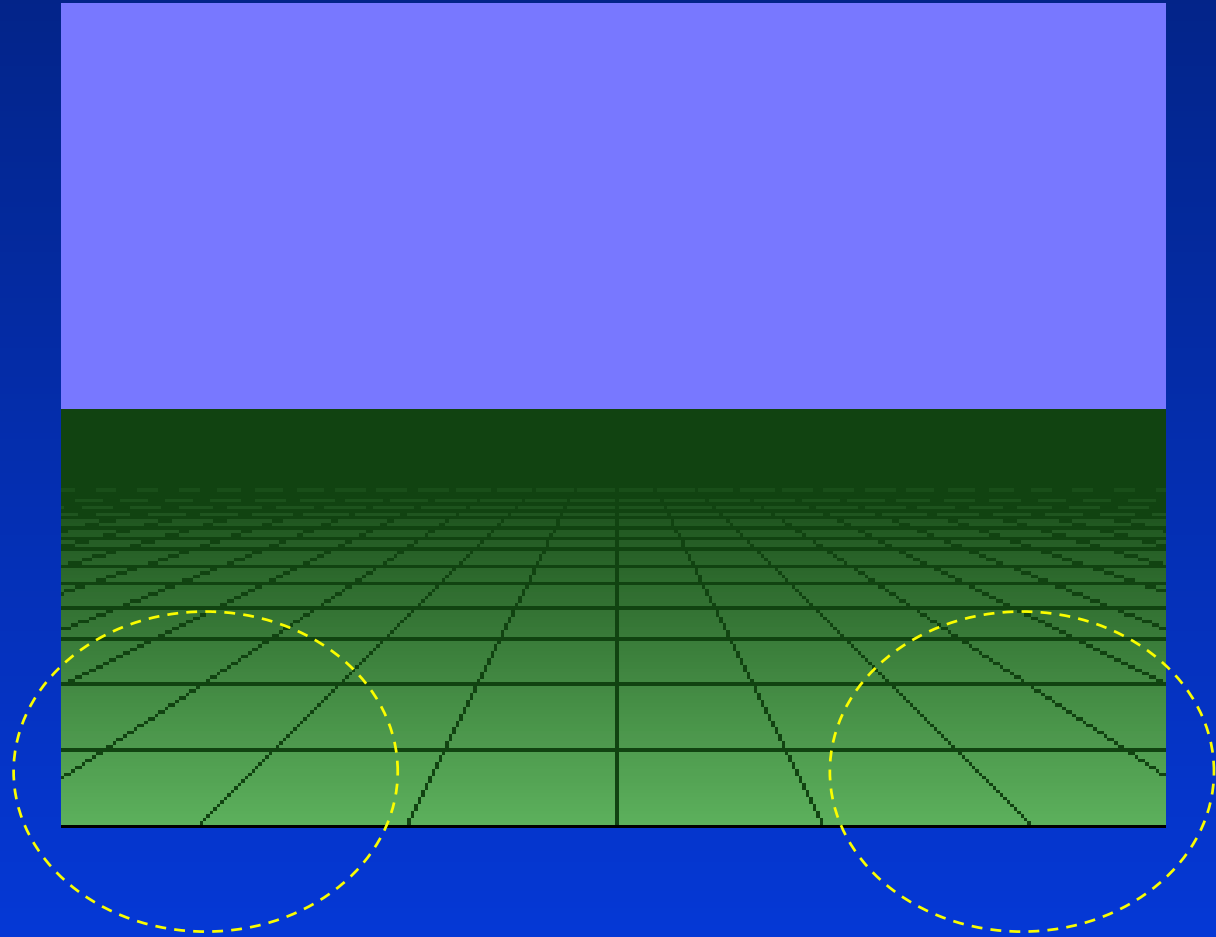
Attitude/Attitude Rates

- **Horizon cue**
 - FOV matched to A/C envelope
 - Augmentation
- **Texture improves rate perception (especially near-field)**
- **Reference to aircraft landmarks important**
- **Camera image can result in reduced control precision**
- **Collimation helps**



Position/Velocity

- **FOV, FOV, FOV**
- **Texture improves velocity control**
- **Ground-based references can aid perception (lines of splay)**
- **Conflicting requirements for position/velocity versus attitude (e.g., spatial resolution vs. FOV)**



Vehicle Dynamics

- **Vehicle dynamics influence information requirements**
- **Velocity/rate information critical for control of acceleration (helicopter, hovering vehicles)**
- **Velocity/rate information less critical for control of velocity/position (fixed-wing aircraft)**
- **Phase of flight affects information requirements**

Motion Perception

- **Texture improves motion perception**
 - Near-field especially important
 - Mismatch of display resolution and scene content can result in aliasing that defeats effective motion perception
- **Slow update rates can compromise motion perception**

Implications for Display Design

- **Consider information requirements**
 - Vehicle
 - Task
 - Phase of flight
- **Consider tradeoffs of camera and display characteristics (FOV/resolution/dynamic range/update rate) to optimize information**
- **Design to satisfy most critical phase**
- **Consider adaptive display and/or information augmentation**

Conclusions

- **Crucial to map display design to perceptual requirements**
- **Perception requirements vary as a function of:**
 - **Control regime**
 - **Vehicle dynamics**
 - **Phase of flight**
- **Future research directions (and wild speculations)**