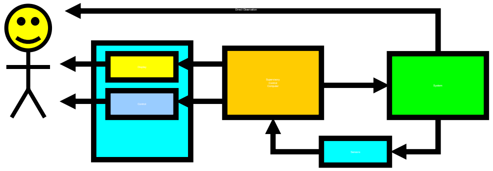
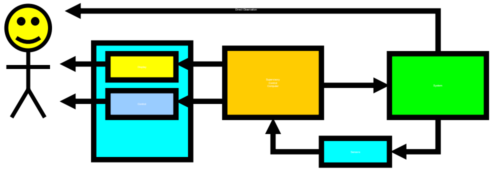


16.422 Human Supervisory Control of Automated Systems

Prof. R. John Hansman

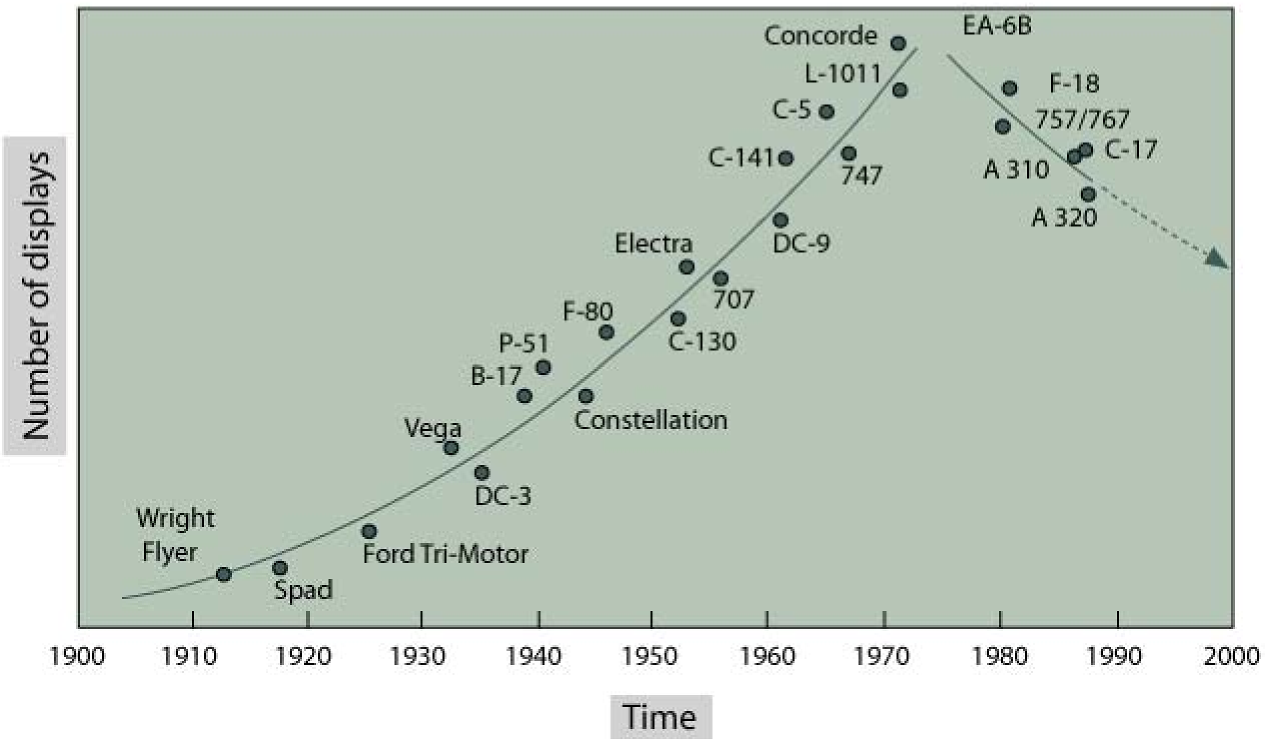
Prof. Missy Cummings



Course Objectives

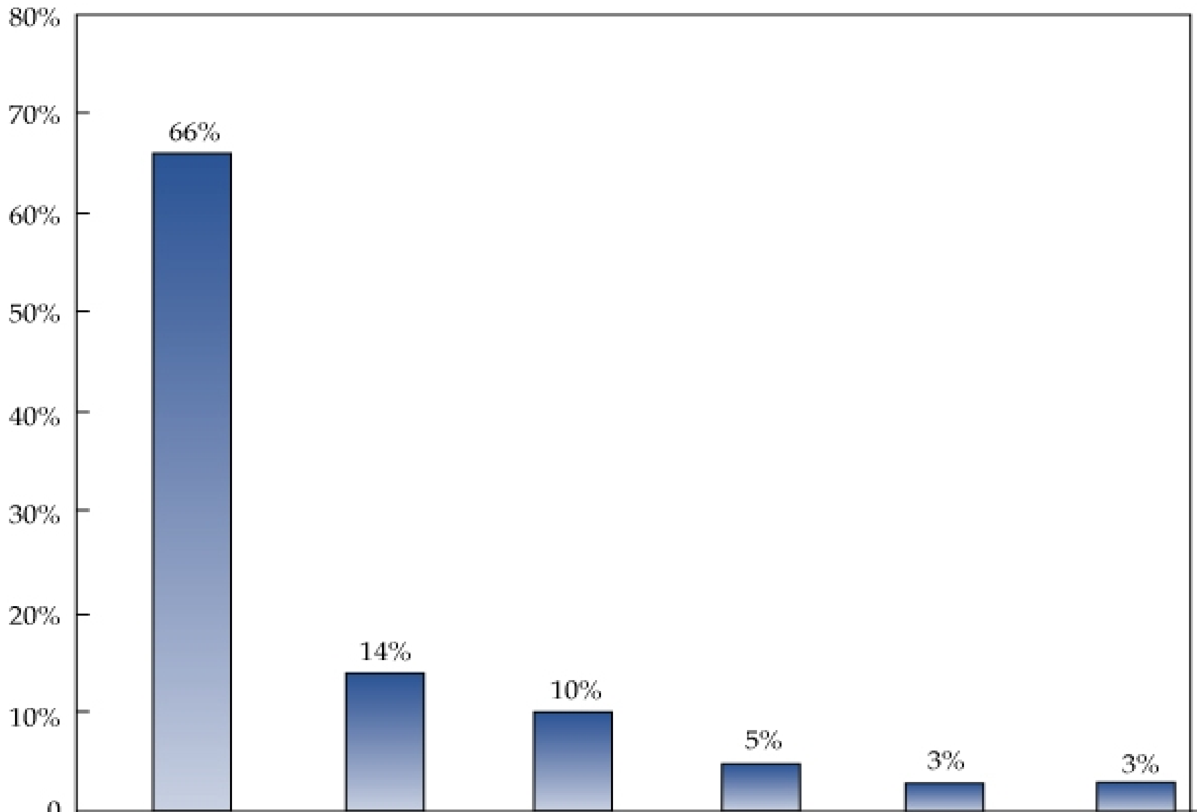
- This is a graduate student class designed to examine the fundamental issues of human supervisory control, wherein humans interact with complex dynamic systems, mediated through various levels of automation. This course will explore how humans interact with automated systems of varying complexities, what decision processes can be encountered in complex man-machine systems, and how automated systems can be designed to support both human strengths and weaknesses. Several case studies will be presented from a variety of domains as illustrations. A secondary objective of this class is to provide an opportunity to improve both oral and written presentation skills.

Evolution of Cockpit Displays



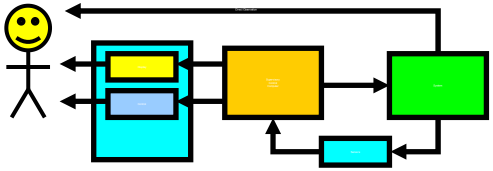
Accidents by Primary Cause*

Hull Loss Accidents - Worldwide Commercial Jet Fleet - 1992 Through 2001



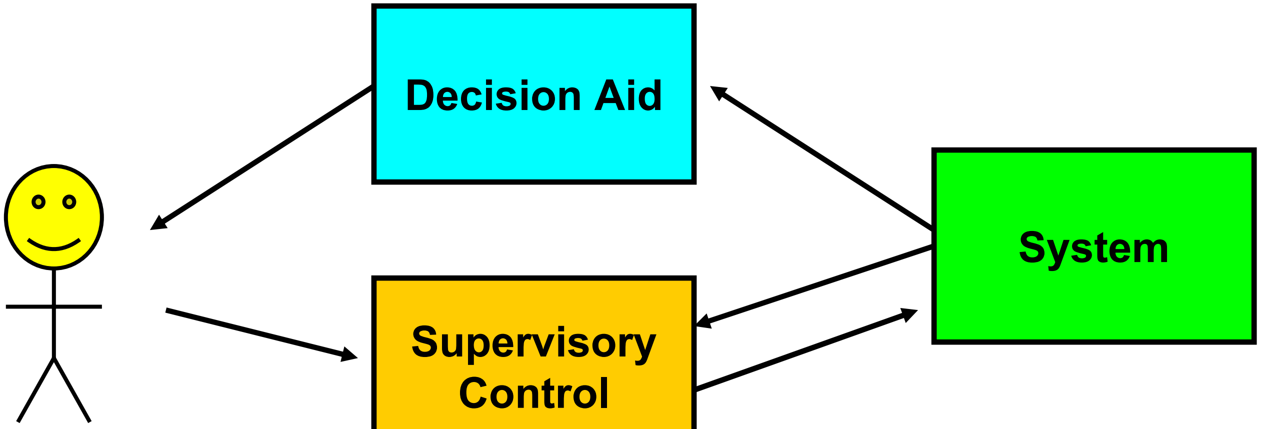
Flight crew	Airplane	Weather	Misc/ Other	Maintenance	Airport/ ATC	Total with known causes	Unknown or awaiting reports	Total
98	21	14	8	4	4	149	61	210

*As determined by the investigative authority

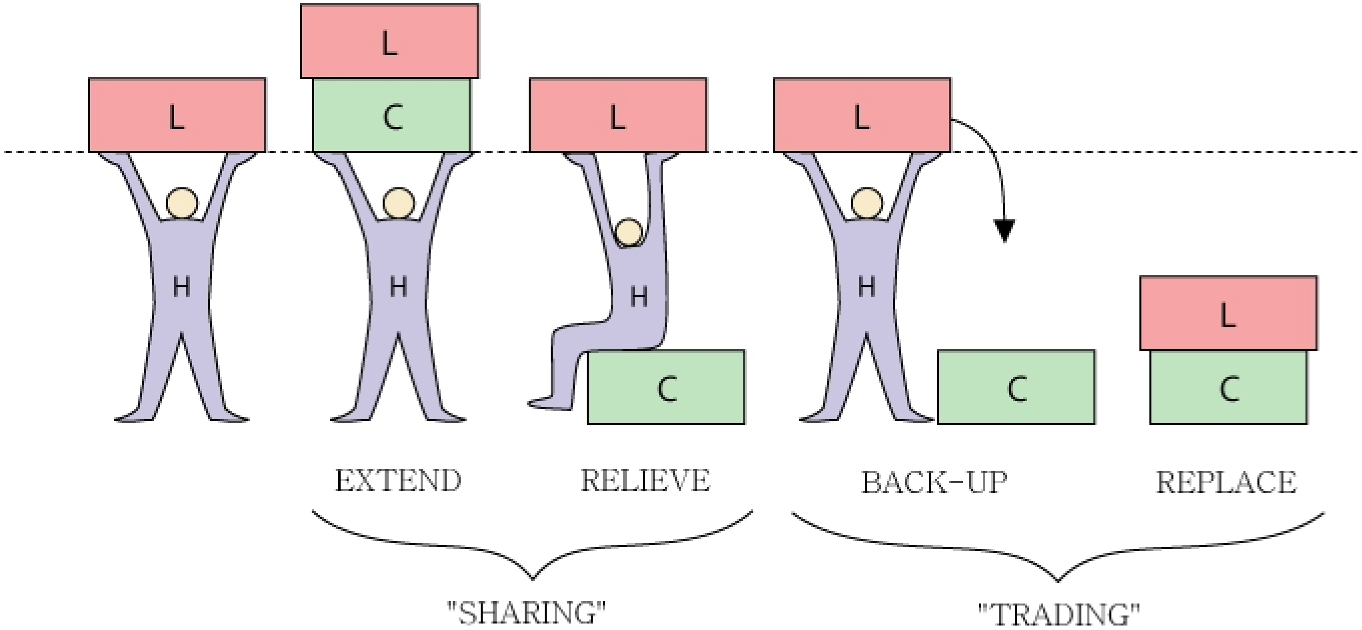


Types of Automation

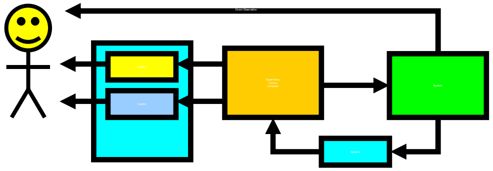
- **Mechanical Automation (eg Factory > Industrial Revolution)**
- **Mixed ; Information and Mechanical (eg Aircraft)**
  - ☐ Decision Aid
  - ☐ Supervisory Control



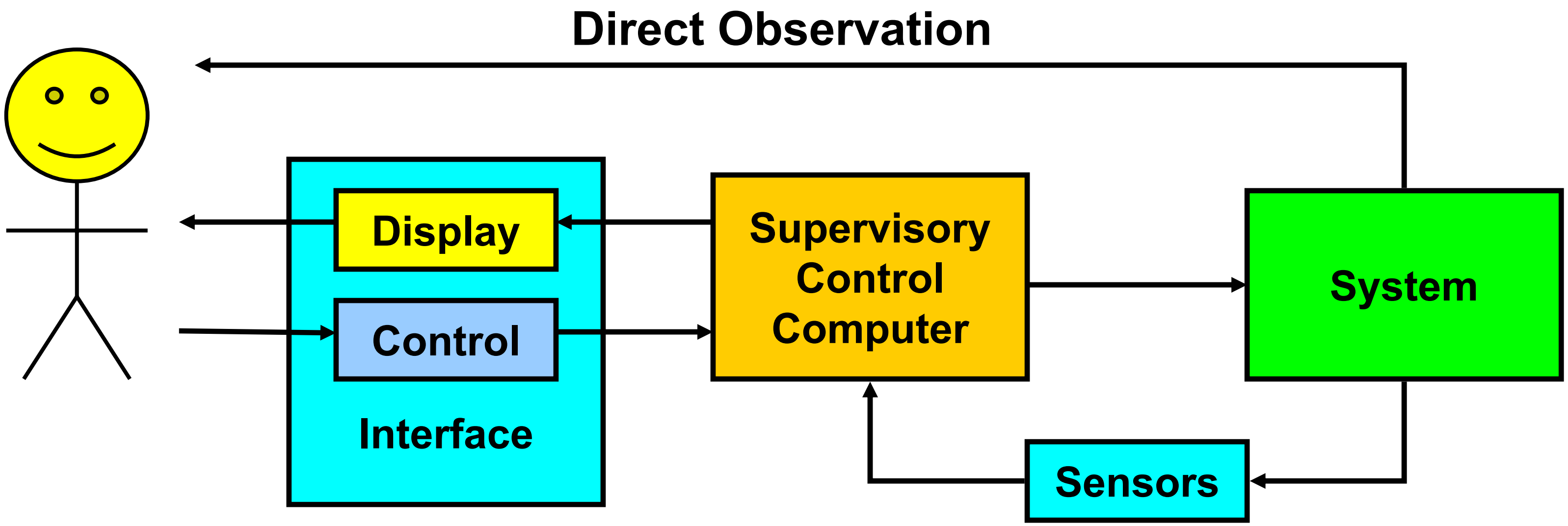
Verplank Notions

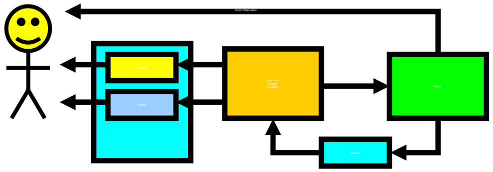


The notions of trading and sharing control between human and computer. L is the load or task, H the human, C the computer. [Adapted from W.Verplank.]



Supervisory Control Architecture

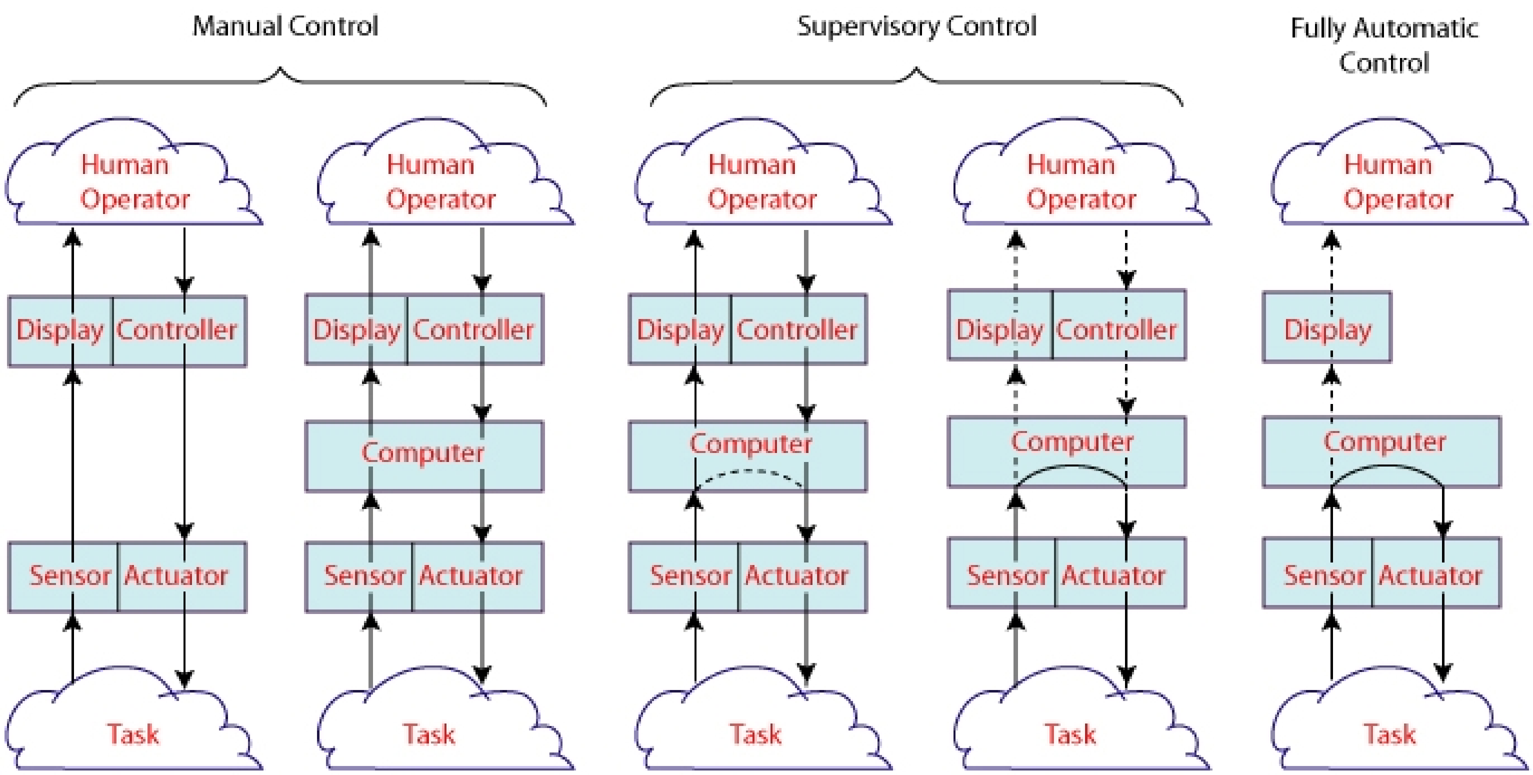


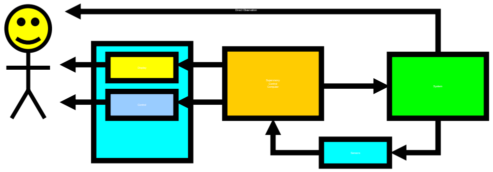


Supervisory Control Examples

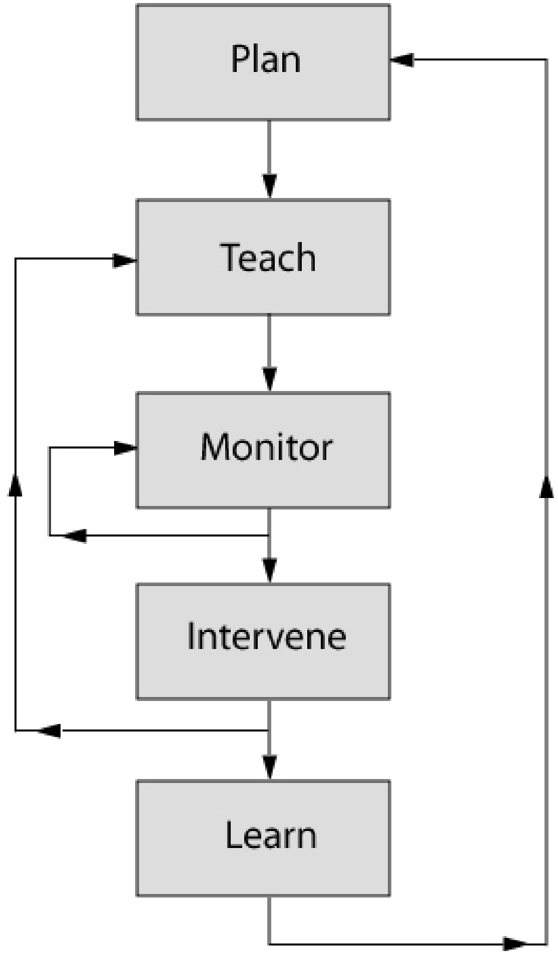
- Autopilot - Flight Management System
- Autonomous Vehicle
- Process Control Plant
- Thermostat
- Word Processing Program
- Cruise Control
- Automated Steering??

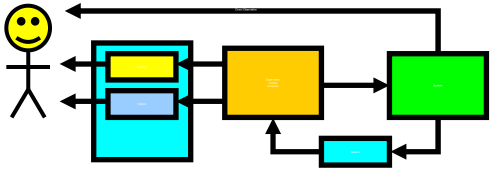
Sheridan Notions
Spectrum of Automation



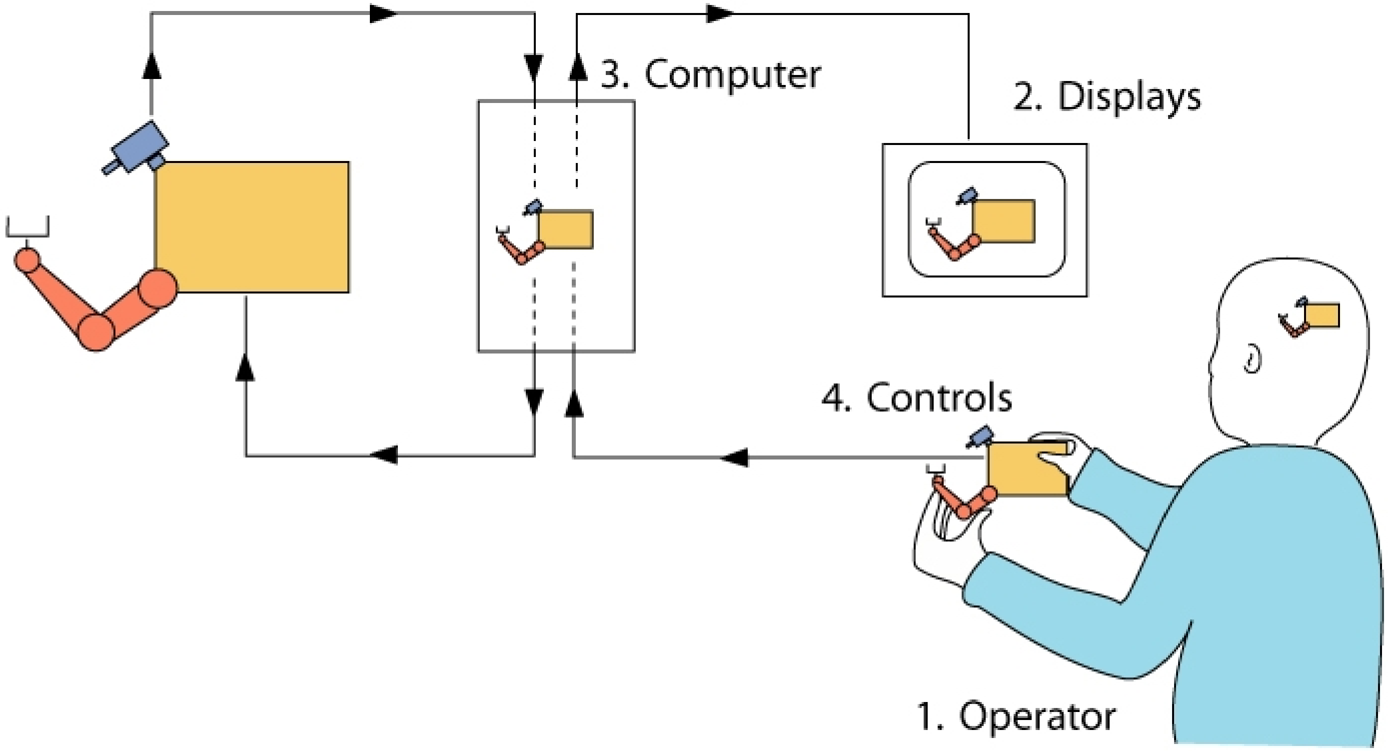


Five supervisor functions as nested loops.

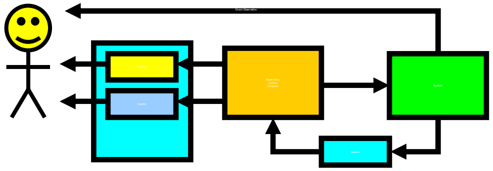




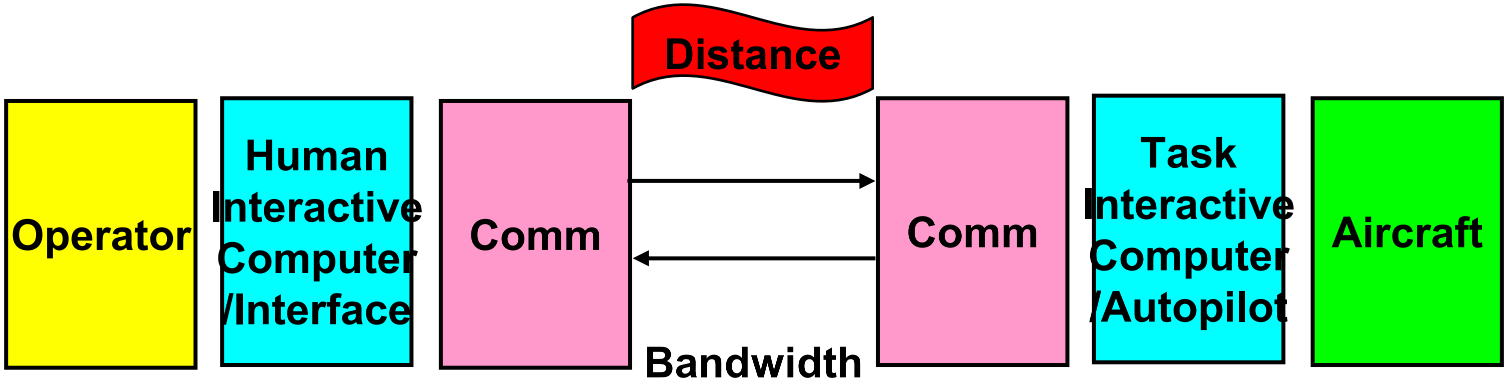
Models



Four loci of models in the supervisory control system: (1) Mental Model (2) Display Representation (3) Control Configuration (4) Computer Model. (Adapted from W. Verplank.)

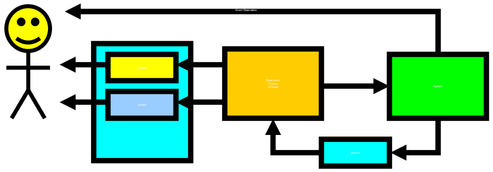


Tele-Systems



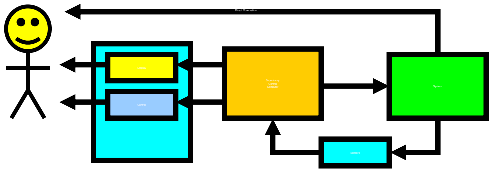
Loss of Direct Feedback
Communications Latency

Task Interactive Computer - Human Interactive Computer

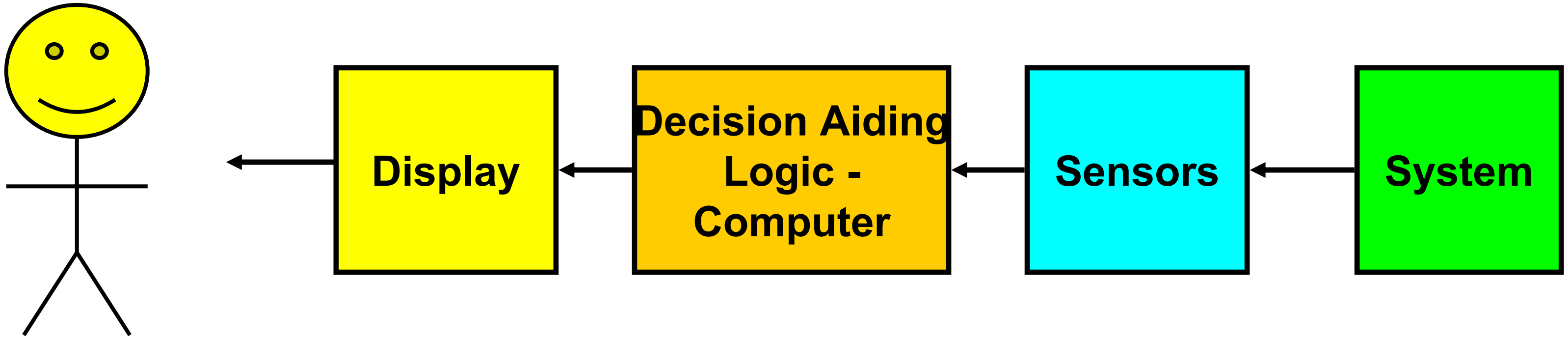


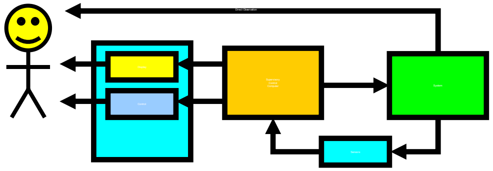
Tele-System Examples

- **Autonomous Vehicle**
  - Aircraft, AAV, RPV
  - Rover - Mars, Bomb
  - Underwater UUV, AUV
- **Web System**
- **Virtual Presence**
- **Tele-medicine**
- **Other**



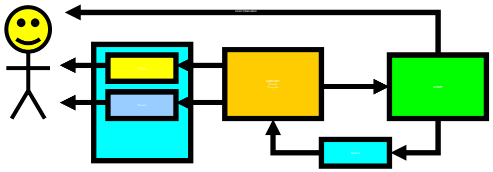
Decision Aid Architecture





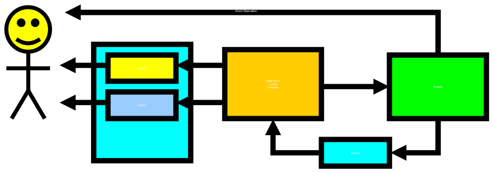
Decision Aid Examples

- **Alerting Systems**
  - ☐ Gear Warning
  - ☐ Idiot Light (eg Oil Pressure)
  - ☐ TCAS
- **Automated Planning Systems**
  - ☐ Path Planners
- **Suggesters**
  - ☐ Spell Check
- **“What if” Tools**
  - ☐ Analysis Tools
- **Data Analysis**
  - ☐ Filters
  - ☐ Interactive Data Analysis Tools

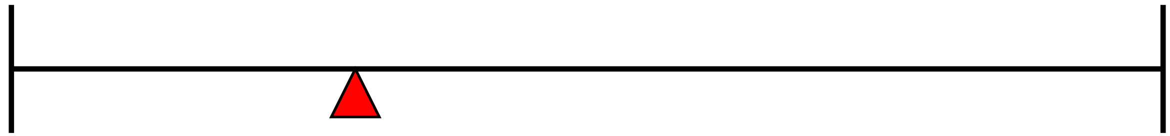


Question

- **What is good design practice for development of human supervisory and decision aiding systems**
  - ☐ Distribution of Authority
  - ☐ Architecture
  - ☐ Intuitiveness of System
  - ☐ Interface Issues
  - ☐ Usability
  - ☐ Performance robustness
  - ☐ Safety
  - ☐ Cost Benefit

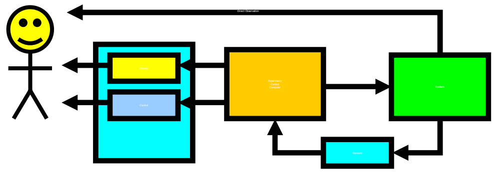


Spectrum of Automation



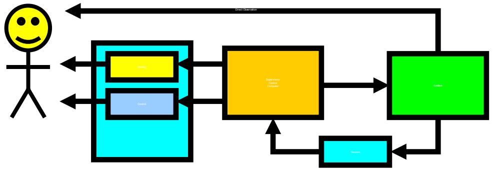
Manual **Fully Autonomous**

- **Historically - Human required to compensate for limitations of system**
  - ☐ Skilled Operators
  - ☐ Training
- **Human limits >>> System Limits**
- **Distribution of Authority (Human vs Automation)**



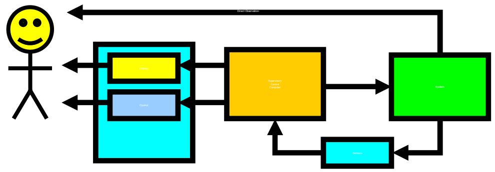
Humans

- **Strengths**
  - Pattern Recognition
  - Inference
  - Data Assimilation
  - Adaptation
  - Intuition
  - Judgment
  - Intuition
  - Morality
- **Limits**
  - Latency - Response time
  - Bandwidth
  - Data Input
    - Visual
    - Audio
    - Tactical
  - Cognitive Capacity
  - Inconsistent Performance
  - Boredom - Saturation
  - Endurance
  - Life Support
  - Cost
  - Training



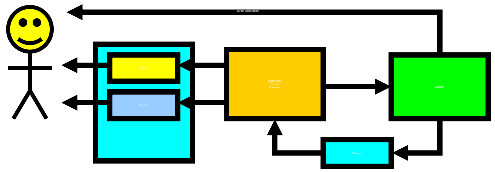
Automation

- **Strengths**
  - ☐ Can be fast
  - ☐ Does not get bored
  - ☐ Consistent
  - ☐ Good for predictable cases
- **Limits**
  - ☐ Dumb
  - ☐ Needs rules
  - ☐ Adaptability
  - ☐ Cost
  - ☐ Input requirements
  - ☐ Interface with system



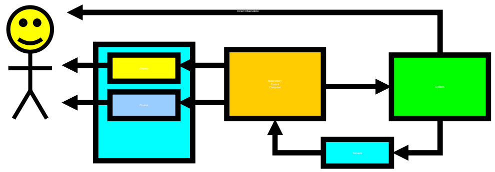
Why Automate ?

- **Enhance Human**
  - ☐ Extend, Relieve, Backup Replace
- **Performance**
  - ☐ Speed, Accuracy, Strength
- **Cost**
  - ☐ 2 person crew
- **Reliability/Repeatability**
- **Hazards to Operators**
  - ☐ UCAV
- **Human Limitations**
  - ☐ G levels, Life Support
- **Market Perception**
- **Distributed Geography**
  - ☐ Telepresece, Web
- **Safety**
  - ☐ True?



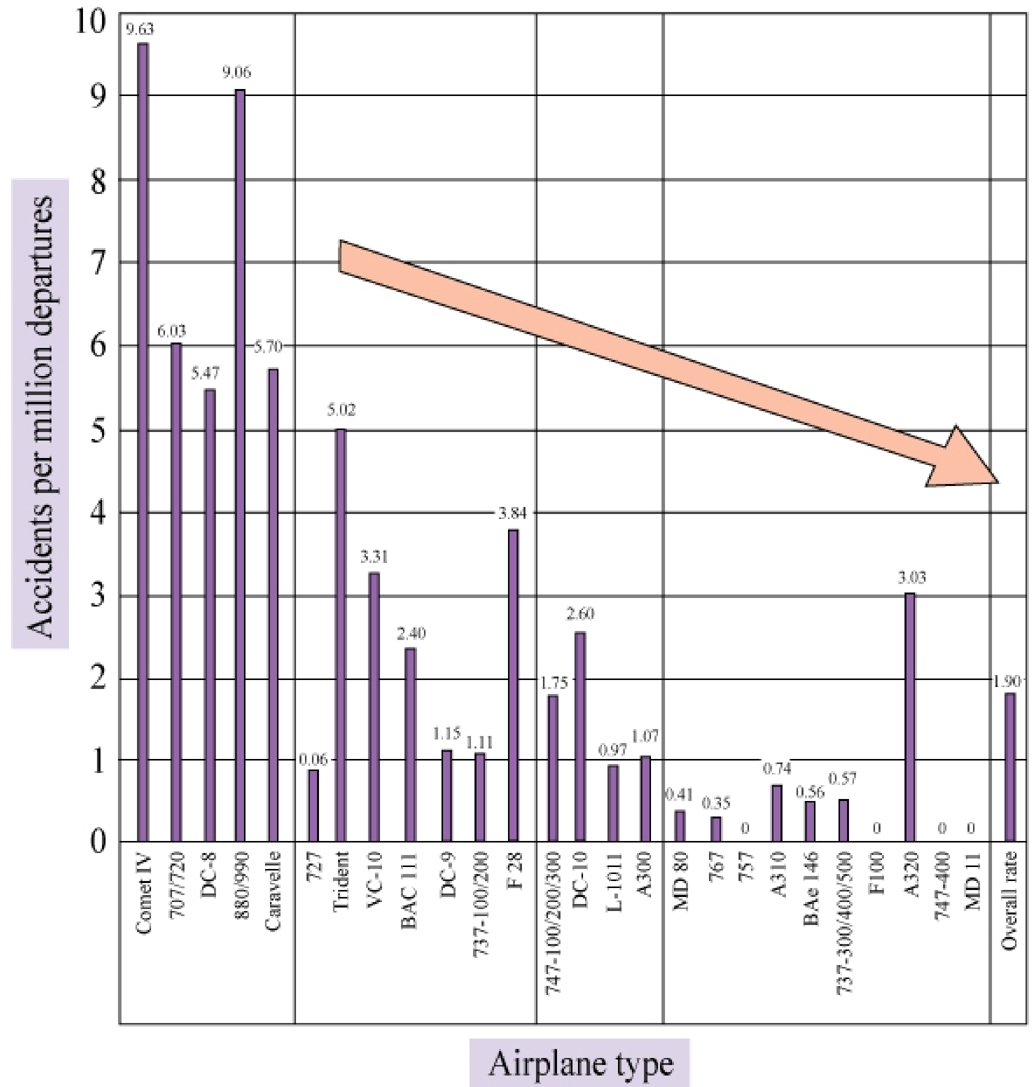
Does Automation Increase Safety?

- **Confounded with other Effects**
  - System Improvements
- **Changes Error Modes**
  - Automation Errors (eg A320)
- **Workload Distribution**
  - Cruise decreased, approach increased
- **System Failure**
  - Over-reliance/Dependence on Automation
- **Complexity Induced Issues**

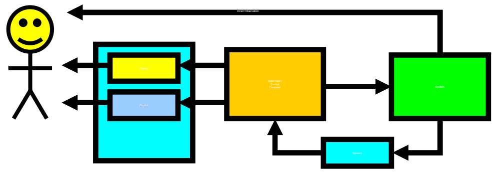


Hull Loss Accidents Rates*

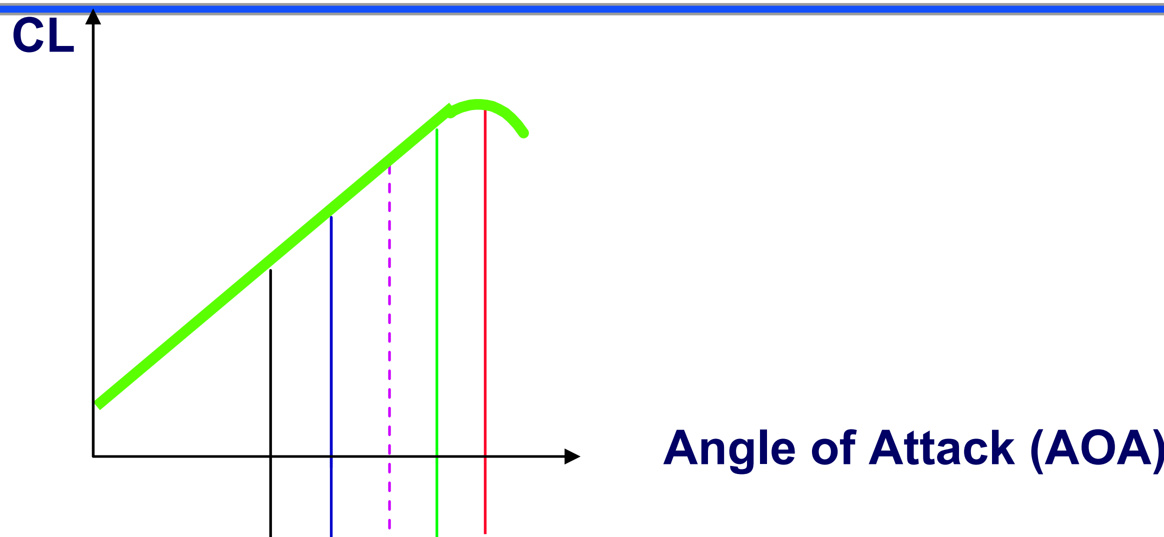
Worldwide Commercial Jet Fleet - 1959-1992

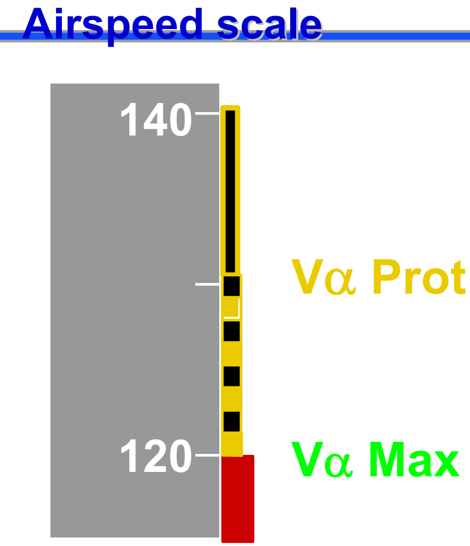


*Excludes : Sabotage, military action.



High Angle of Attack Protection





α Stall: Sudden loss of lift and or aircraft control

α Max: Angle of attack reached with full aft stick (max aircraft performance)

α Floor: **Angle of attack, where TOGA thrust is** automatically applied by the A/THR

α Prot: **Angle of attack from which stick input is converted into angle of attack demand (stick neutral α Prot)**

VLS Angle of attack reached at approach speed (VLS)

A320 Thrust Control

Thrust levers

- Moved manually (no servomotor)
- Transmit their position to the respective FADEC (Full Authority Digital Engine Control)