Functional Allocation Issues and Tradeoffs (FAIT)
Analysis of a SVS

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Model Roles

- Typical Analyses Narrow Problem Down
  - Probability estimates
  - Consequences
  - Establish system performance requirements
- FAIT Opens Problem Up
  - What might happen?
  - How?

Questions Addressed by a FAIT Analysis

- What might go wrong?
- What types of errors (human and system) might occur?
- What types of conditions or scenarios?
- What requirements should be written to prevent errors?
- What design solutions?
- What tradeoffs?
- How should development resources be allocated?

Benefits of the FAIT Analysis

- Can be used early in the design process
- Can be used to explore prototypical systems that have yet to be implemented
- Assists in identifying information requirements
- Yields numerical values that represent the relative ***influence*** and the relative ***sensitivity*** of the important aspects within the system
- Allows for the examination of tradeoffs in a human-machine system
- Allows inclusion of purely psychological constructs (e.g. mental workload)

FAIT Applications

- Advanced Air Transport Technologies
- Cockpit Display of Traffic Information (Free Flight)
- Airborne Information for Lateral Spacing (AILS)
- Synthetic Vision System

Preliminary Step (Define the Components of the System)

- **The Human:**
  - We focused on the pilot flying (PF) with regards to the SVS system. However, ATC personnel, as well as other crew members, will occasionally be considered to the extent which they affect the PF.
- **The Environment:**
  - Although the SVS is capable of supporting all phases of flight, we focused only on approach and landing.

Preliminary Step (Define the Components of the System)

- VIRTUAL VISUAL ENVIRONMENT:
  - Mimics what could be seen out the window in good visibility conditions
  - Uses either a photo-realistic terrain display, a less detailed terrain texture display, or a wire-frame rendering of terrain
  - Display is head-down
  - May have three possible display sizes (757 EADI 5 x 5.25 inch, 777 PFD 6.4 x 6.4 inch, and rectangular flat-panel 8 x 10 inch)
  - May have four possible, pilot selectable, field of views
  - PFD symbology is overlaid on the SVS display (this is not selectable)
  - Obstacles in proximity of own aircraft are displayed via the terrain database
  - Runway edges are depicted
  - Salient features can be highlighted on the display
  - Pilot has the ability to declutter the display
  - The SVS will give an auditory or visual warning if impact with terrain is imminent
  - The pilot manually enters flight path data into the SVS (or through the FMS)
- PRIMARY FLIGHT INFORMATION:
  - Primary flight information is overlaid on the SVS display
  - Primary flight information is not redundantly coded elsewhere in the cockpit

Step 1 (Create a Model of Information Flow)

Automation Taxonomy

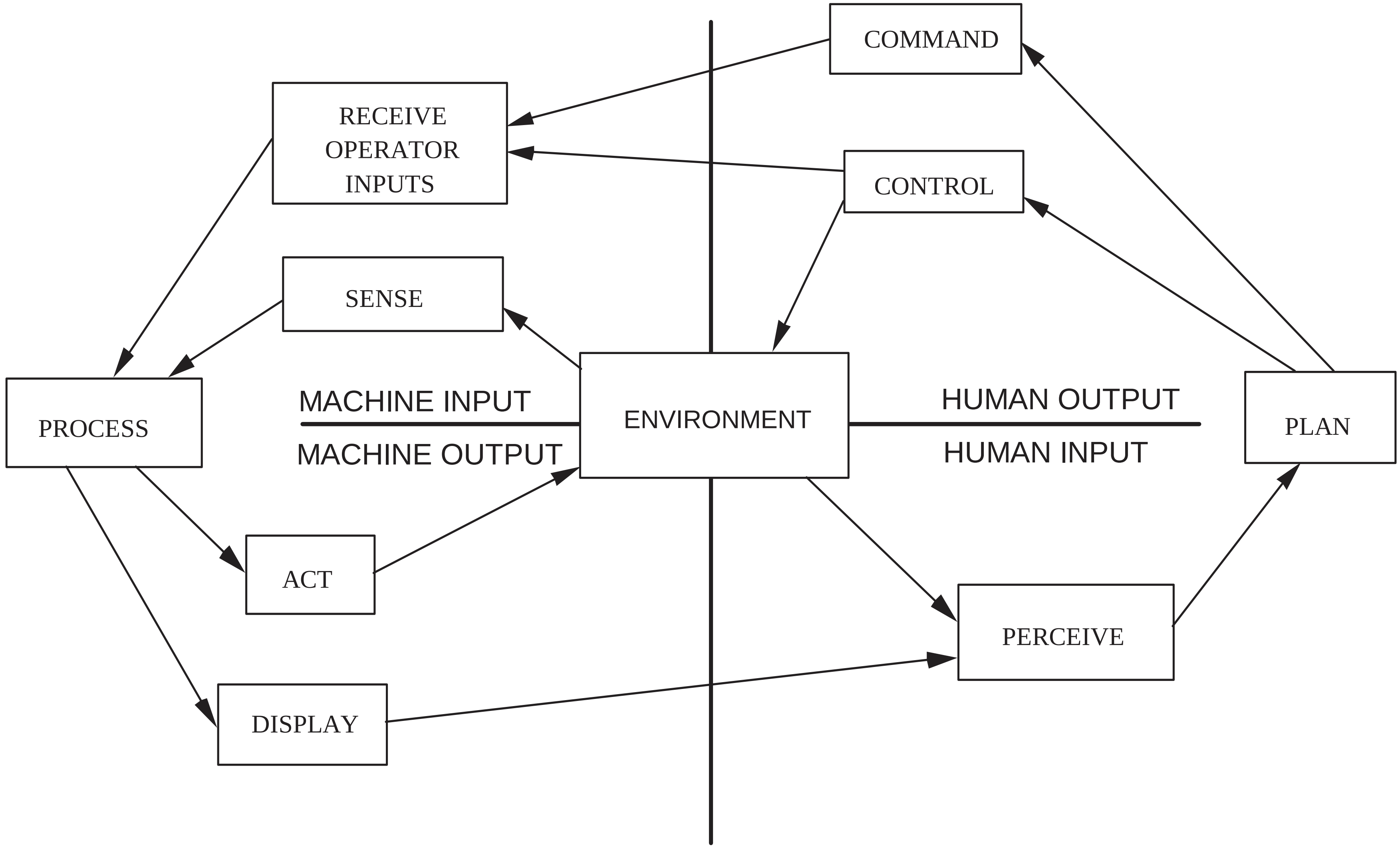
LEVELS OF INTELLIGENCE

LEVELS OF AUTONOMY	raw data	procedural	context responsive	personalized	inferred intent responsive	operator state responsive	operator predictive
none							
information fuser							
simple aid							
advisor							
interactive advisor							
adaptive advisor							
servant							
assistant							
associate							
partner							
supervisor							
autonomous							

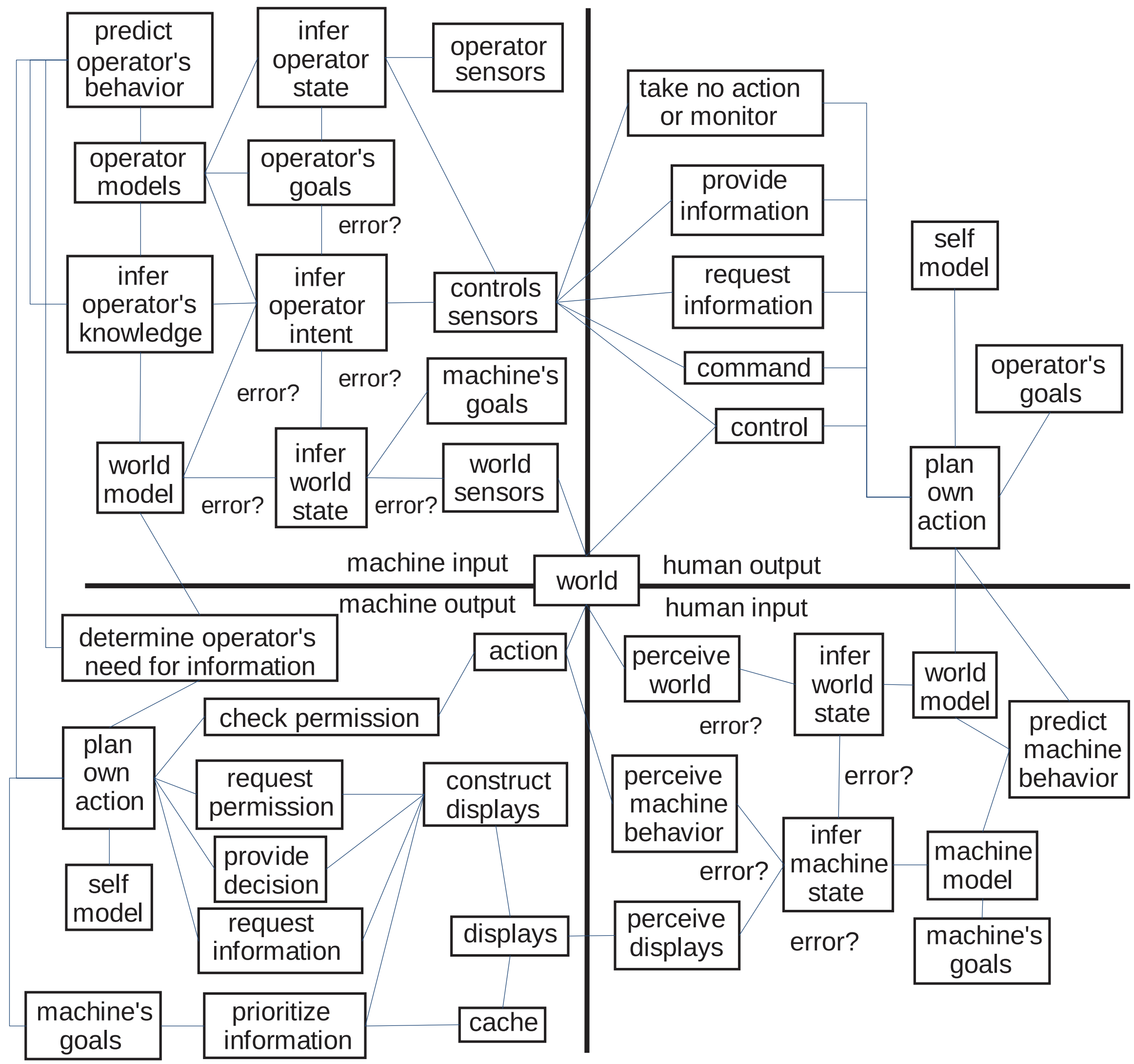
Step 1 (Create a Model of Information Flow)

- Automation: Information Fuser
  - This refers to automation that can collect information and put it in the best format for presentation to the operator
- Intelligence: Personalized
  - This refers to automation that can be "personalized" to perform or present information the way a particular operator wants it
  - This level of automation was chosen because aspects of the SVS, such as FOV, are selectable

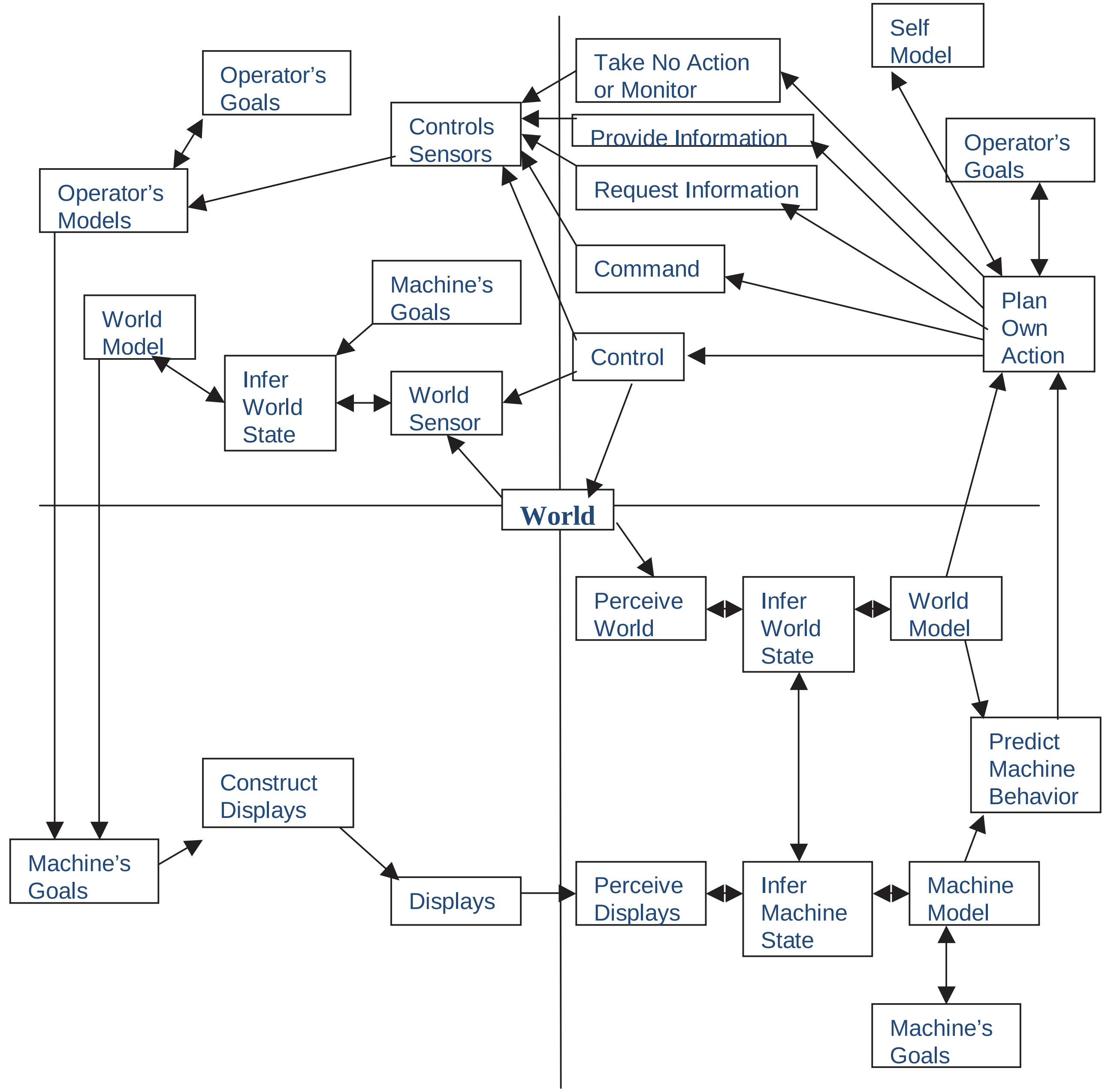
GENERAL MODEL



FULL MODEL


predict operator's behavior
infer operator state
operator sensors
operator models
operator's goals
error?
infer operator's knowledge
infer operator intent
controls sensors
machine's goals
error?
error?
world model
infer world state
world sensors
error?
error?
take no action or monitor
provide information
request information
command
control
self model
operator's goals
plan own action
machine input
world
human output
machine output
human input
determine operator's need for information
action
perceive world
infer world state
world model
check permission
error?
predict machine behavior
plan own action
request permission
construct displays
perceive machine behavior
error?
provide decision
infer machine state
machine model
self model
error?
request information
displays
perceive displays
error?
machine's goals
machine's goals
prioritize information
cache

Information Flow Chart: Personalized/Information Fuser



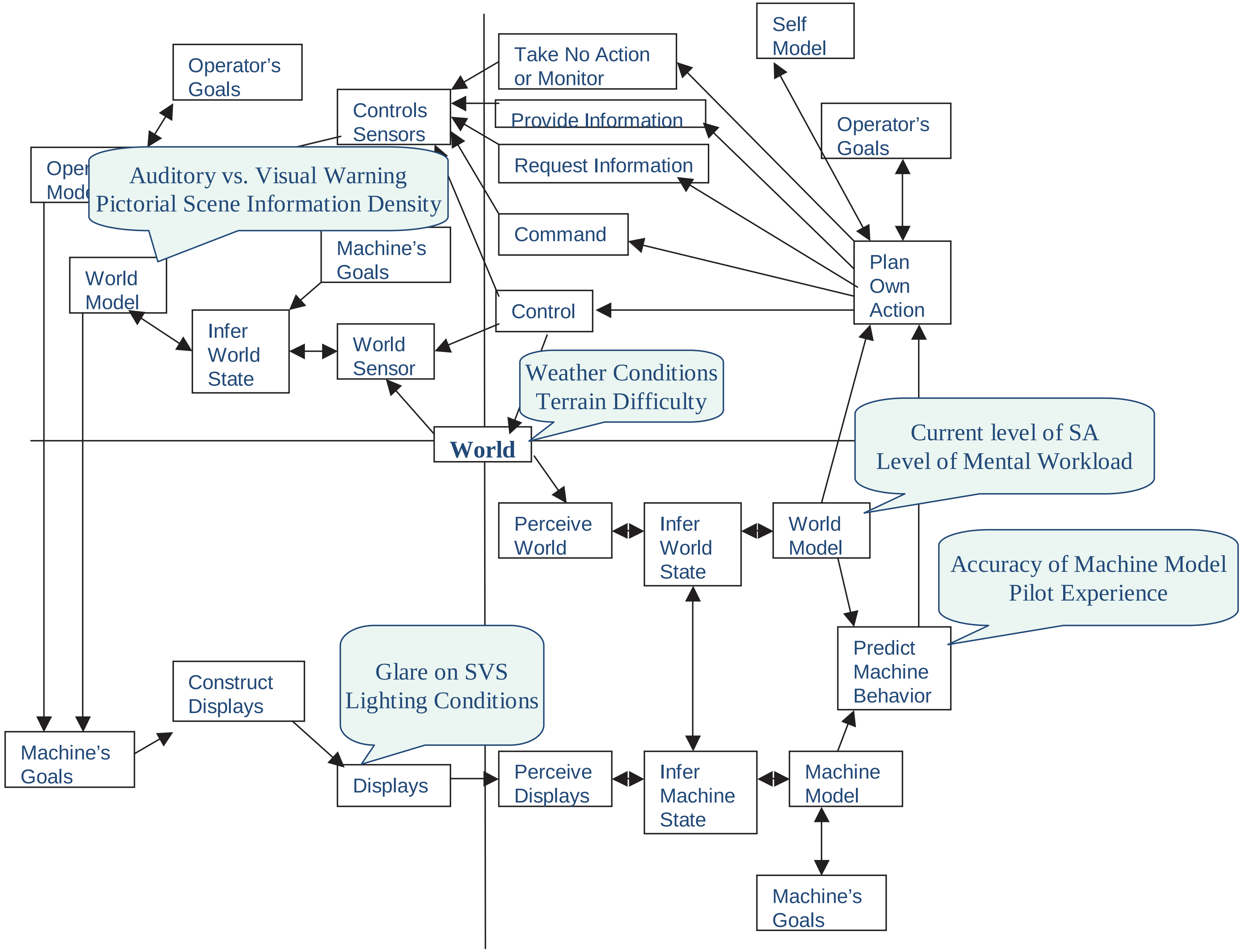
Step 2: Determine Characteristics

- Step 2a: Characteristics are determined for each node in the information flow model
  - A characteristic can be defined as “an important aspect of the system that can vary from a desirable to an undesirable state”
  - An example would be “Level of mental workload” and “Degree of display clutter”
  - Other characteristics pertaining to the SVS itself that did not fit this definition were also included such as “Display Size” and “Pictorial Scene information density”

Step 2b

- **A questions was asked for each node in the information flow model in order to determine characteristics**
- **World Model Node:**
- *Represents the operators level of understanding about the operational environment*
- *What affects the pilots current mental model of (or awareness of) the SVS environment?*
- *Examples Include:*
  - Current level of SA
  - Amount of time spent viewing the SVS display
  - Amount of display cross-checking
  - Amount of time spent looking out-the-window
  - Experience using the SVS
  - Intuitiveness/usability of the SVS
  - Functioning/malfunctioning of displays other than the SVS
  - Number of highlighted features currently in view
  - Accuracy of pilots mental model of the environment
  - Degree of pilot fatigue

Information Flow Chart: Personalized/Information Fuser



Step 3: Create a Matrix

- Step 3: Each characteristic is listed twice in a matrix, once as a ***driver*** and once as a ***receiver***
- The cells in the matrix represent all possible interactions between characteristics

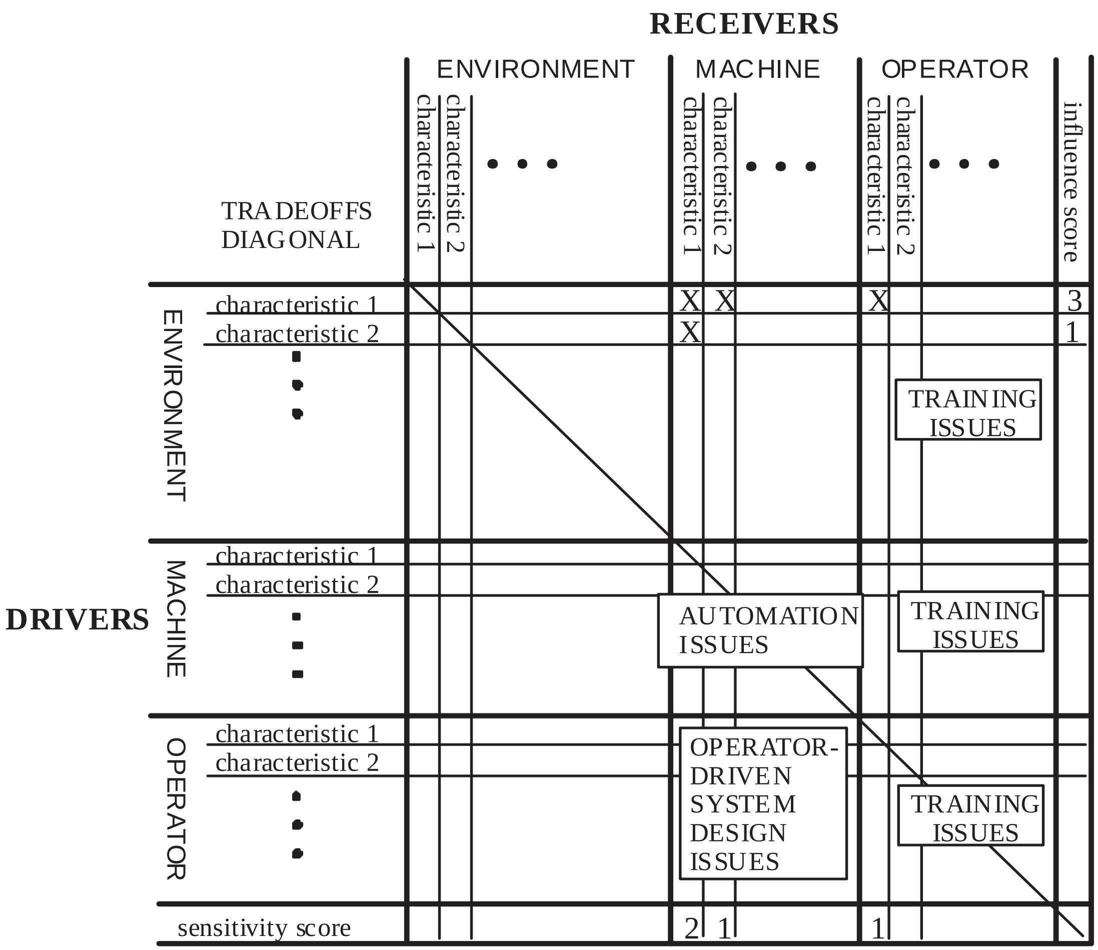
Step 4

- **For each cell, two questions are asked:**
  - 1.) Does the ***driver*** influence the ***receiver*** during real time operations of the system?
  - 2.) Does the ***driver*** characteristic place a requirement on the ***receiver*** characteristic?
    - For example, when the volume of noise (*driver*) in the cockpit is high, a visual warning (*receiver*), as opposed to an auditory warning, may be required.
- **If the answer to either question is “Yes” an entry is made in the matrix**

Example of the SVS Matrix

Receivers / Drivers	Difficulty of approach	Difficulty of landing	Difficulty of terrain environment at destination airport	Functioning/malfunctioning of displays other than the SVS	Accuracy of pilots mental model of the environment	Amount of time spent looking out-the-window	Amount of time spent reading instruments other than the SVS	Amount of time spent viewing the SVS display	Current level of SA	Level of mental workload	Accuracy of GPS	Accuracy of terrain database	Intuitiveness/usability of the	Pictorial scene i
Drivers														
Difficulty of approach		1				1	1	1	1	1			1	
Difficulty of landing						1	1	1	1	1			1	
Difficulty of terrain environment at destination airport	1	1			1	1	1	1	1	1			1	
Functioning/malfunctioning of displays other than the SVS	1	1			1	1	1	1	1	1				
Accuracy of pilots mental model of the environment	1	1							1	1				
Amount of time spent looking out-the-window	1	1			1		1	1	1	1				
Amount of time spent reading instruments other than the SV	1	1			1	1		1	1	1				
Amount of time spent viewing the SVS display	1	1			1	1	1		1	1				
Current level of SA	1	1			1	1	1	1						
Level of mental workload	1	1			1	1	1	1	1				1	
Accuracy of GPS	1	1			1	1	1	1	1	1				
Accuracy of terrain database	1	1			1	1	1	1	1	1				
Intuitiveness/usability of the SVS	1	1			1	1	1	1	1	1				1
Pictorial scene information density	1	1			1	1	1	1	1	1			1	

FAIT Structure



Most Influential Characteristics Overall

- Intuitiveness/usability of the SVS
- Difficulty of terrain environment surrounding destination airport
- Experience and ability of the pilot
- Difficulty of approach
- Accuracy of GPS
- Accuracy of terrain database
- Difficulty of landing
- Functioning/malfunctioning of displays other than the SVS
- Pilot preference
- Limitations of the machines processor
- Pictorial scene information density

Most Sensitive Characteristics Overall

- Level of mental workload
- Difficulty of landing
- Difficulty of approach
- Amount of time spent reading instruments other than the SVS
- Amount of time spent viewing the SVS display (head-down time)
- Current level of SA
- Accuracy of pilots mental model of the environment
- Amount of time spent looking out-the-window

Most Influential/Sensitive Characteristics in the “Environment” Category

- Difficulty of terrain environment at destination airport (I)
- Difficulty of landing (I/S)
- Difficulty of approach (I/S)
- Functioning/malfunctioning of displays other than the SVS (I)
- ATC workload (S)
- Altitude of aircraft (S)
- Speed of aircraft (S)

Most Influential/Sensitive Characteristics in the "Operator" Category

- Experience and ability of the pilot (I)
- Pilot preference (I)
- Experience using the SVS (training) (I)
- Amount of display cross-checking (I)
- Amount of time spent looking out-the-window (I/S)
- Amount of time spent viewing the SVS display (I/S)
- Level of pilot mental workload (I/S)
- Amount of time spent reading instruments other than the SVS (S)
- Current level of SA (S)
- Accuracy of pilots mental model of the environment (S)

Most Influential/Sensitive Characteristics in the "Machine" Category

- Intuitiveness/usability of the SVS (I/S)
- Accuracy of the GPS (I)
- Accuracy of the terrain database (I)
- Limitations of the machines processor (I)
- Pictorial scene information density (I)
- Glare on the SVS (I)
- Degree of display clutter (S)
- Degree of overlay with PFD data (S)
- Auditory vs. visual warning (S)
- Display size (S)
- Color of symbols/text (S)
- Color of terrain (S)
- FOV currently depicted on the SVS display (S)

What do these characteristic Suggest?

- These ratings suggest that these characteristics are essential to the functioning of the SVS system
- For example, the following states should be avoided because of their potential to seriously interfere with the functioning of the SVS system:
  - The PF has low SA
  - The PF has little experience
  - The PF has a high mental workload
  - The PF spends little time viewing the SVS display
  - The PF has an inaccurate mental model of the SVS/environment
  - There is a high degree of display clutter/overlay with PFD data
  - The terrain database or GPS is inaccurate or not functioning properly
  - **This is an incomplete list**

Step 5: Identify Tradeoffs

- Tradeoffs are determined by identifying symmetrical relationships within the matrix
- Tradeoffs exist because the driver influences the receiver, and vise versa
- An abbreviated matrix which identifies the most influential and sensitive characteristics in each category (world, pilot, and machine) was used to identify the most "important" tradeoffs
  - (A total of 77 potential tradeoffs were identified in the full matrix, and 37 potential tradeoffs were identified in the abbreviated matrix)

Step 5: Identify Tradeoffs

- In order for there to be a true tradeoff situation, there must be a strictly inverse relationship between the characteristics
- Each characteristic must be considered as a driver and as a receiver, and as desirability increases for one and decreases for the other
- Four scenarios were written for each of the 37 potential tradeoffs
- Although true tradeoff relationships are not common, the scenarios identify potential human factors problems in the SVS, and may be further used in SV simulations

Examples of Potential Tradeoffs

Step 6: Identify Information Requirements for the System

- Three Questions are asked for each cell in the abbreviated matrix:
  - *Whose knowledge* of the situation would assist in prevention, detection, or mitigation of the error?
  - *What knowledge* would assist in the prevention, detection, or mitigation of the error?
  - *What information* is necessary for the appropriate person to obtain the necessary knowledge

    - **This step has not yet been completed

Conclusions