22
Humans as a System Component

Distributed Embedded Systems

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November 23, 2015

Carnegie Mellon

Preview

◆ **People as components of systems**

  • Factors affecting people

  • Strengths and weaknesses compared to machines
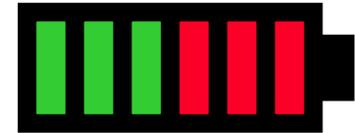

◆ **Usability / User interfaces**

  • What tends to make things usable?

  • What user interfaces work well?

A Word About Human Computer Interaction

◆ **Not everyone is a 21 year old male engineering student**

  - (Nor a female engineering student!)
  - So don't design as if that is who your user population is
  - There are experts in the area of HCI – use them!

How full is this battery?

◆ **Consider how well your system will work with these populations:**

  - Non-English speakers
  - Left-handed (7-10% of population)
  - Color blind (esp. red/green – 7-10% of population)
  - Presbyopia (most people over 45 or so)
  - Polarized sunglasses (LCDs are also polarized; sometimes the wrong way)
  - Hearing impaired; wearing hearing protection
  - Gloves, coats, hats
  - Children (size, weight, child-proofing)
  - Arthritis (can't manipulate small knobs, e.g., childproofing mechanisms)
  - Pets (e.g., cat on keyboard)

Human-Computer Interaction Issues

◆ **Donald MacKenzie – 1994**

[Donald MacKenzie, *Knowing Machines: Essays on Technical Change.* Cambridge, MA: MIT Press, 1996.]

- 1,100 computer-related accidental deaths (1979-1992)

- 4% of deaths due to physical sources
- 3% of deaths due to software error
- 92% of deaths due to human-computer interaction
  - (Will this change as software gets more control authority?)

◆ **For example, in aviation, "controlled flight into terrain" (pilot error) is a common accident cause**

- John Denver (the singer) was arguably killed by a poor user interface in a flying accident (fuel reserve tank switch on bulkhead behind him)

Software for Certain Medtronic Implanted Infusion Pumps Recalled

FDA Patient Safety News: Show #32, October 2004

Medtronic is recalling certain software application cards. They're used in the company's Model 8840 N'Vision Clinician Programmers. These hand-held devices are used to program a number of implantable devices, including the SynchroMed and SychroMed EL implantable infusion pumps.

The recall is prompted by reports of data entry errors that have led to serious drug overdoses, including two patient deaths. The overdoses occurred when clinicians who were programming the pump entered the wrong time duration or the wrong interval --- for example, mistakenly putting the time interval between periodic drug boluses in the "minutes" field, instead of the "hours" field.

The recalled software may have contributed to these errors because one part of the screen did not have labels on the fields for hours, minutes, and seconds. Medtronic is now distributing replacement software that adds time labels to the screen to help reduce the risk of these kinds of programming errors.

If you use the Model 8840 N'Vision Programmer with SynchroMed or SynchroMed EL infusion pumps, the company says you should pay particular attention to selecting the appropriate time field when entering time duration or time intervals. You should also be sure to check your software application card for your N'Vision Programmer. If you have the older software version (AAA 02), Medtronic says you should order the new version (AAD 02).

http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/psn/printer.cfm?id=261

Things Humans Are Good At

◆ **Detecting correlations and exceptions**

- Patterns/clusters in graphical data
- Breaks in lines

◆ **Detecting isolated movement**

- Waving
- Blinking
- But not many things moving at once

◆ **Detecting the difference between "nothing" and "something"**

- Sounds: alarms, acoustic nulling
- Lights: on vs. off rather than brightness
- Touch: shaking vs. smooth

Advantages of People Over Machines

- ◆ **Sensing/Actuating**
  - Excellent dynamic sensor range (logarithmic response to stimuli)
    - – Hearing: 20 Hz – 20 KHz; 0 dB – 140 dB   (factor of 10^{14} in energy)
    - – Eye neurons can respond to a single photon;
      about 9 photon "hits" for people to get enough signal to say they saw light
  - Excellent image processing, especially edge & anomaly detection
  - Flexibility; ability to improvise actuations and tools

- ◆ **Cognition**
  - Ability to improvise in ill-structured situations
  - Able to make speed/accuracy tradeoffs

  - Machines do exactly what you tell them to do

- ◆ **Issues that can be improved**
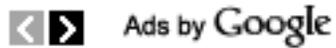 - Repeatability & predictability can be improved with intense training

Both Pilots Asleep While Approaching Denver

Published by Michael November 1st, 2007 in Aviation Safety.

Lawmakers meeting about airline safety Wednesday heard about a government report that described a commercial pilot and his first officer falling asleep at the wheel 60 miles outside from Denver, and careening toward the airport at twice the speed allowed.

A commercial pilot had recently switched schedules to flying three "red eyes" in a row between Denver and Baltimore with only one hour in between flights. On March 4, 2004, during the third late-night flight, the pilot and his first officer were approaching Denver in an Airbus A319 and they were fast asleep.

"LAST 45 MINS OF FLT I FELL ASLEEP AND SO DID THE FO,"

"MISSED ALL CALLS FROM ATC," the report continues, saying that the plane was supposed to be traveling at less than 290 mph, but they were moving at a clip of about 590 mph.

"I WOKE UP, WHY I DON'T KNOW, AND HEARD FRANTIC CALLS FROM ATC. … I ANSWERED ATC AND ABIDED BY ALL INSTRUCTIONS TO GET DOWN. WOKE FO UP," the report says, adding that he then followed all the controller's instructions, "AND LANDED WITH NO FURTHER INCIDENTS."

Continue at source: http://www.foxnews.com/story/0,2933,307019,00.html

http://blog.flightstory.net/370/both-pilots-asleep-while-approaching-denver/

Army Surgeon General: Sleepy Soldiers as Impaired as Drunk Soldiers

M Oct 15, 2014 | by Bryant Jordan

The Army's surgeon general said the "new frontier" deploying agile and sharp soldiers is ensuring the soldier has a healthy brain.

"When we're talking about cognitive dominance [by our soldiers] you absolutely have to focus on ensuring a healthy brain, ensuring that [they] have that mental agility," Lt. Gen. Patricia D. Horoho said Wednesday during a presentation entitled The Human Dimension at the Association of the U.S. Army's annual conference in Washington, DC.

Part of maintaining a healthy brain is ensuring soldiers get enough sleep. The Army has understood the importance of sleep, but Horoho said this has often been disregarded by unit leaders who believe "that we're being effective when we're sleep deprived."

"If you have less than six hours of sleep for six days in a row you have a cognitive impairment of 20 percent – that you are cognitively impaired as if you had a.08 percent alcohol level," she said. "We never will allow a soldier in our formation with a .08 percent alcohol level, but we allow it every day to make those complex decisions."

http://www.military.com/daily-news/2014/10/15/army-surgeon-general-sleepy-soldiers-as-impaired-as-drunk.html

Advantages of Machines Over People

◆ **Sensing/Actuating**

- Can sense beyond human ranges
- Sensors/actuators can directly interface with harsh environments
- Actuation generally unaffected by fatigue

◆ **Cognition**

- They don't fall asleep!
- No boredom; especially effective at dealing with infrequent (but anticipated) situations
- Precise and accurate computations
- Less overhead for multitasking than for people
- Repeatable & predictable

- Machines do exactly what you tell them to do

Should You Trust People Or Machines?

◆ **Boeing trusts people**

- Pilot has ultimate authority
  - The pilot is the final authority for the operation of the airplane.

◆ **Airbus trusts machines**

- Machine has ultimate authority
  - Automation must not lead the aircraft out of the safe flight envelope and it should <u>maintain the aircraft within the normal flight envelope</u>.
  - <u>Within the normal flight envelope</u>, the automation must not work against operator inputs, except when absolutely necessary for safety
- Several close calls because pilot had difficulty over-riding machines
- Hard to say how many incidents were avoided by automation, but probably a lot

See: http://www.crm-devel.org/resources/paper/autophil.htm

Role of Drivers in Automated Vehicles?

◆ **Should we trust driver to be attentive in case of automation failure?**

http://www.bbc.com/news/magazine-25861214

Factors Affecting Performance [Hollnagel93]

- ◆ **Operator experience**
- ◆ **Training quality**
- ◆ **Time available**
- ◆ **Procedure quality**
- ◆ **Supervision quality**
- ◆ **Noise**
- ◆ **Accessibility**
- ◆ **Use of checklist**
- ◆ **Motivation**

- ◆ **Information quality**
- ◆ **Stress**
- ◆ **Communication**
- ◆ **Team structure**
- ◆ **Design**
- ◆ **Location**
- ◆ **Cognitive complexity**
- ◆ **Physical complexity**
- ◆ **Perception of consequences**

- ◆ **Best possible performance is about 10^{-4} error rate per action**
  - Improves to 10^{-5} error rate for well-trained team doing double-checks
  - These assume calm, everyday, trained nuclear power plant operations

# Stress & Haste Reduce Operator Performance

Table 16.5 (cont.)

Human error probability	Activity
$2^{(n-1)}x$	Given severe time stress, as in trying to compensate for an error made in an emergency situation, the initial error rate, x, for an activity doubles for each attempt, n, after a previous incorrect attempt, until the limiting condition of an error rate of 1.0 is reached or until time runs out. This limiting condition corresponds to an individual's becoming completely disorganized or ineffective
~1.0	Operator fails to act correctly in first 60 seconds after the onset of an extremely high stress condition. e.g. a large LOCA
0.9	Operator fails to act correctly after the first 5 minutes after the onset of an extremely high stress condition
10^{-1}	Operator fails to act correctly after the first 30 minutes in an extreme stress condition
10^{-2}	Operator fails to act correctly after the first several hours in a high stress condition
x	After 7 days after a large LOCA, there is a complete recovery to the normal error rate, x, for any task

Note   LOCA: Loss of coolant accident (break in the primary circuit)

Table 16.5 Human error probabilities used in US nuclear reactor safety study (PRA, 1975)

Human error probability	Activity
10^{-4}	Selection of a key-operated switch rather than a non-key switch (this value does not include the error of decision where the operator misinterprets situation and believes key switch is correct choice)
10^{-3}	Selection of a switch (or pair of switches) dissimilar in shape or location to the desired switch (or pair of switches), assuming no decision error. For example, operator actuates large handled switch rather than small switch
3×10^{-3}	General human error of commission, e.g. misreading label and therefore selecting wrong switch
10^{-2}	General human error of omission where there is no display in the control room of the status of the item omitted, e.g. failure to return manually operated test valve to proper configuration after maintenance
3×10^{-3}	Errors of omission, where the items being omitted are embedded in a procedure rather than at the end as above
3×10^{-2}	Simple arithmetic errors with self-checking but without repeating the calculation by re-doing it on another piece of paper
$1/x$	Given that an operator is reaching for an incorrect switch (or pair of switches), he selects a particular similar appearing switch (or pair of switches), where x = the number of incorrect switches (or pair of switches) adjacent to the desired switch (or pair of switches). The $1/x$ applies up to 5 or 6 items. After that point the error rate would be lower because the operator would take more time to search. With up to 5 or 6 items he does not expect to be wrong and therefore is more likely to do less deliberate searching

[Villemeur]

10^{-1}	Given that an operator is reaching for a wrong motor operated valve (MOV) switch (or pair of switches), he fails to note from the indicator lamps that the MOV(s) is (are) already in the desired state and merely changes the status of the MOV(s) without recognizing he had selected the wrong switch(es)
~1.0	Same as above, except that the state(s) of the incorrect switch(es) is (are) not the desired state
~1.0	If an operator fails to operate correctly one of two closely coupled valves or switches in a procedural step, he also fails to correctly operate the other valve
10^{-1}	Monitor or inspector fails to recognize initial error by operator. Note: With continuing feedback of the error on the annunciator panel, this high error rate would not apply
10^{-1}	Personnel on different work shift fail to check condition of hardware unless required by checklist or written directive
5×10^{-1}	Monitor fails to detect undesired position of valves, etc., during general walk-around inspections, assuming no checklist is used
0.2–0.3	General error rate given very high stress levels where dangerous activities are occurring rapidly

[Villemeur]
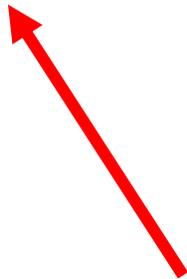
Description	Human-error probability
1. General rate for errors involving very high stress levels	0.3
2. Complicated non-routine task, with stress	0.3
3. Supervisor does not recognise the operator's error	0.1
4. Non-routine operation, with other duties at the same time	0.1
5. Operator fails to act correctly in the first 30 minutes of a stressful emergency situation	0.1
6. Errors in simple arithmetic with self-checking	0.03
7. General error rate for oral communication	0.03
8. Failure to return the manually operated test valve to the correct configuration after maintenance	0.01
9. Operator fails to act correctly after the first few hours in a high-stress scenario	0.01
10. General error of omission	0.01
11. Error in a routine operation where care is required	0.01
12. Error of omission of an act embedded in a procedure	0.003
13. General error rate for an act performed incorrectly	0.003
14. Error in simple routine operation	0.001
15. Selection of the wrong switch (dissimilar in shape)	0.001
16. Selection of a key-operated switch rather than a non-key-operated switch (EOC)	0.0001
17. Human-performance limit: single operator	0.0001
18. Human-performance limit: team of operators performing a well-designed task, very good PSFs, etc.	0.00001

[Kirwan94]

Reaction Times

Reaction times vary according to different factors, as shown in the following.

By Sense Preceptor	sec
Touching	.11–.15
Temperature	.15–.22
Pain	.70–1.00
Hearing	.12–.22
Smelling	.29
Tasting	.20–1.10
Seeing	.15–.20
Eyes to focus	.165
Eyes move to 40° without focusing	.10

By Age	sec
5 years	.40
10 years	.30
20 years	.20
30 years	.22
40 years	.25
50 years	.38
55 years	.35
60 years	.50

Reaction time varies with sex: men take 0.1 second less for sound and light than women.

Reaction time varies with limbs: feet take 20% more time than hands.

The left hand, for the right-handed, takes 3% more time than the right hand.

Reaction time varies with training; with practice, it can be reduced 10%.

Reaction time varies with signal characteristics. The minimum signal period is 0.2 seconds. Short signals of 0.1 second are not good. Alerting signals can reduce reaction time up to 40%.

An illustration of total reaction time follows: A pilot sees an approaching plane through the haze:

1. The pilot detects a plane (eye moves)	0.3 sec
2. Intercepts image (perception)	0.6
3. Selects course of action (decision)	0.5
4. Pilot moves control (response)	0.3
Total reaction time	1.7 sec

If both planes are headed toward one another at 400 mph, each pilot has only 1,000 feet before a collision. That distance will be covered in the 1.7 seconds of reaction time.

[Tilley93]

Other Human Factors Data Nuggets

◆ **Human time perception in computer interfaces**

- Less than 100 msec is instantaneous
  - With more than ~100 msec lag, hand-eye coordination becomes more difficult
- Less than 1 second is fast enough to be "interactive"
  - After about 1 second, productivity goes down due to loss of train of thought
- Less than 10 seconds if fast enough that user doesn't assume things failed
  - After 10 seconds, web users usually assume page is broken

◆ **SAE J2364 navigation standard (for automobiles)**

- Driver should not glance away from road for more than 15 seconds
- 15 seconds @ 100 kph = 416 meters

◆ **UK Def-std 00-25 is a set of freely available human factors standards**

- http://www.dstan.mod.uk/

Errors of Commission & Omission

◆ **Generally errors of omission are more common**

  • "Forgot to do something" more common than doing wrong thing

  • Checklists are best way to handle omission errors

Human Perception Of Risk

◆ **The "Dread Risk" effect**

- People might fear calamities more than everyday mortalities
  - Nuclear war; Nuclear power
  - Aircraft
  - Cars; Walking
- The fear is non-linear with risk, and increases with scope (and news coverage) of catastrophic failures

◆ **"Risk Homeostasis" – sometimes people change behavior**

- Anti-lock brakes seem to encourage people to follow more closely
- Cars are arguably "safer," but in the end, risk wasn't been changed

◆ **Degree of perceived control affects reactions**

- A person controlling a vehicle experiences less perceived risk
  - Even if their ability to actually control the vehicle is not as good as another person's
  - Most drivers think they have "above average" ability (above median ability too)

Usability Principles [Nielsen93]

1. Simple and Natural Dialogue (simple; no distractions)
2. Speak the user's language (know your audience)
3. Minimize user's memory load

    • (Involves the 7 +/-2 rule and limit to 3 levels of recursion)

4. Consistency
5. Feedback
6. Clearly marked exits (undo and cancel facilities)
7. Shortcuts (accelerators)
8. Good error messages
9. Design that avoids common error sources
10. Help and documentation

◆ **Plus: play to strengths of user physiology/psychology**

Good Error Messages [Nielsen93]

- **Phrased in clear language and avoid obscure codes**
  - User should understand error message without having to refer to manual

- **Precise rather than vague or general**
  - Bad: "Cannot open this document"
  - Good: "Cannot open 'Chapter 5' because the application is not on the disk

- **Constructively help the user solve the problem**
  - Guess what the user meant to do
  - Suggest corrective actions, e.g., correct misspelled words

- **Error messages should be polite and not intimidate the user**
  - Users feel bad enough as it is when they make mistakes
  - Avoid screaming at the user
  - Bad: "ILLEGAL USER ACTION, JOB ABORTED"
    - Does this mean a SWAT team will be showing up to arrest the user?
    - MS Windows used to have an "illegal instruction" pop-up; but not anymore

An Example User Interface

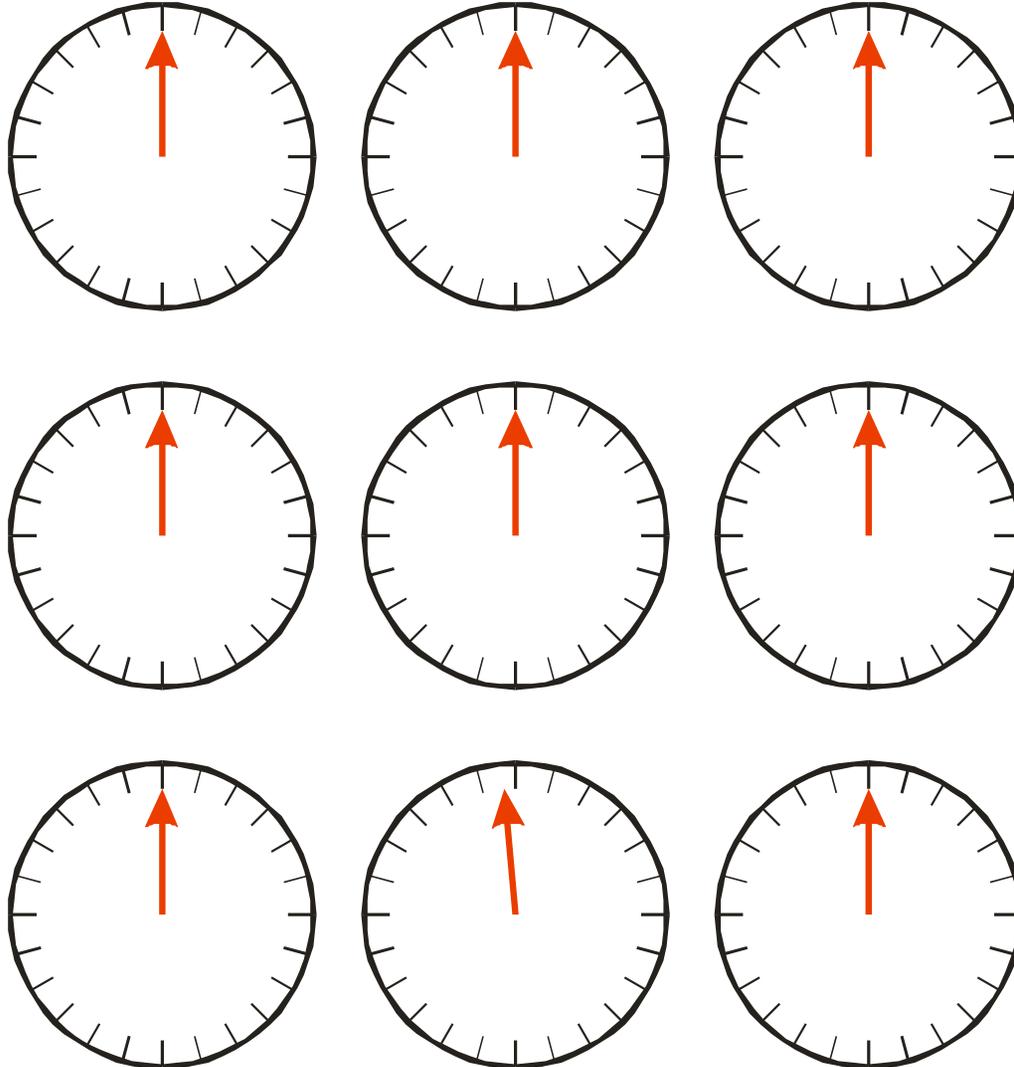◆ **Bad interface – which dial is abnormal?**

• General rule – put "normal" at 12 O'clock position
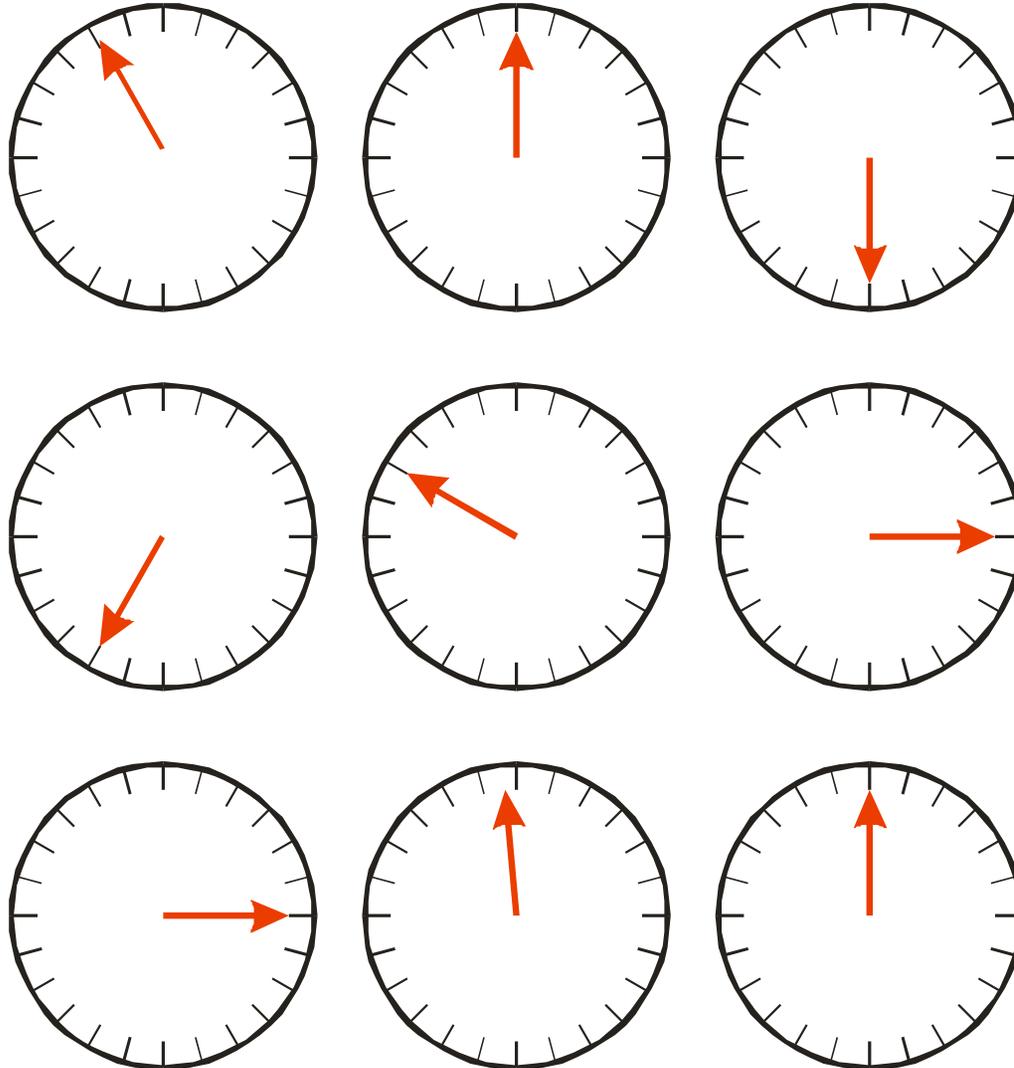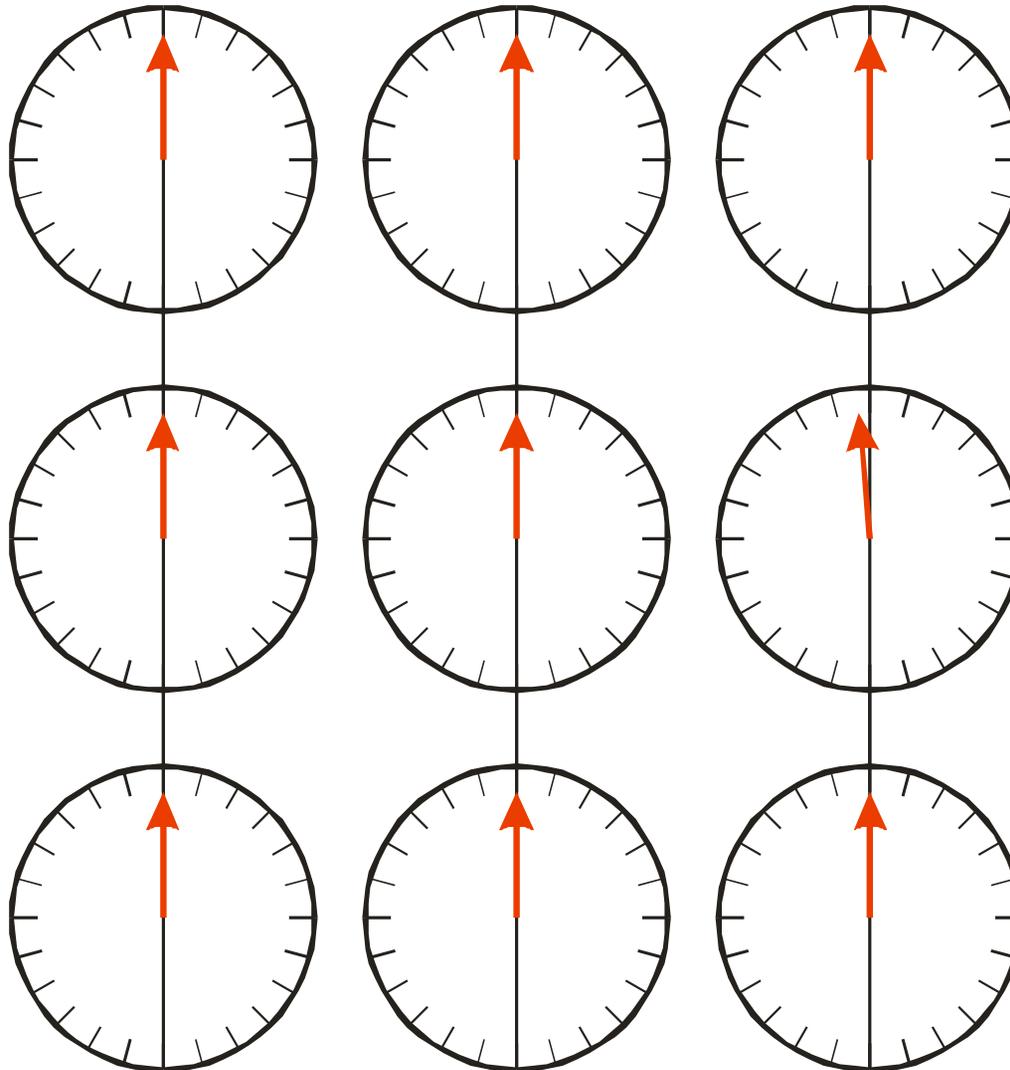
OK, But Could Be Better

◆ **Which dial isn't at 12:00 "normal" position?**

- How would you like to try to find it 4 times per minute?

Exploiting Human Eye Edge/Line Detection

◆ **Only 5 degree change is readily perceptible**

Example Usability Problem

◆ **How do you flush this toilet without getting sprayed in the face?**

Human Interface Guidance

◆ **There are experts for user interfaces**

  • Often a good idea to have them do design reviews on user interfaces
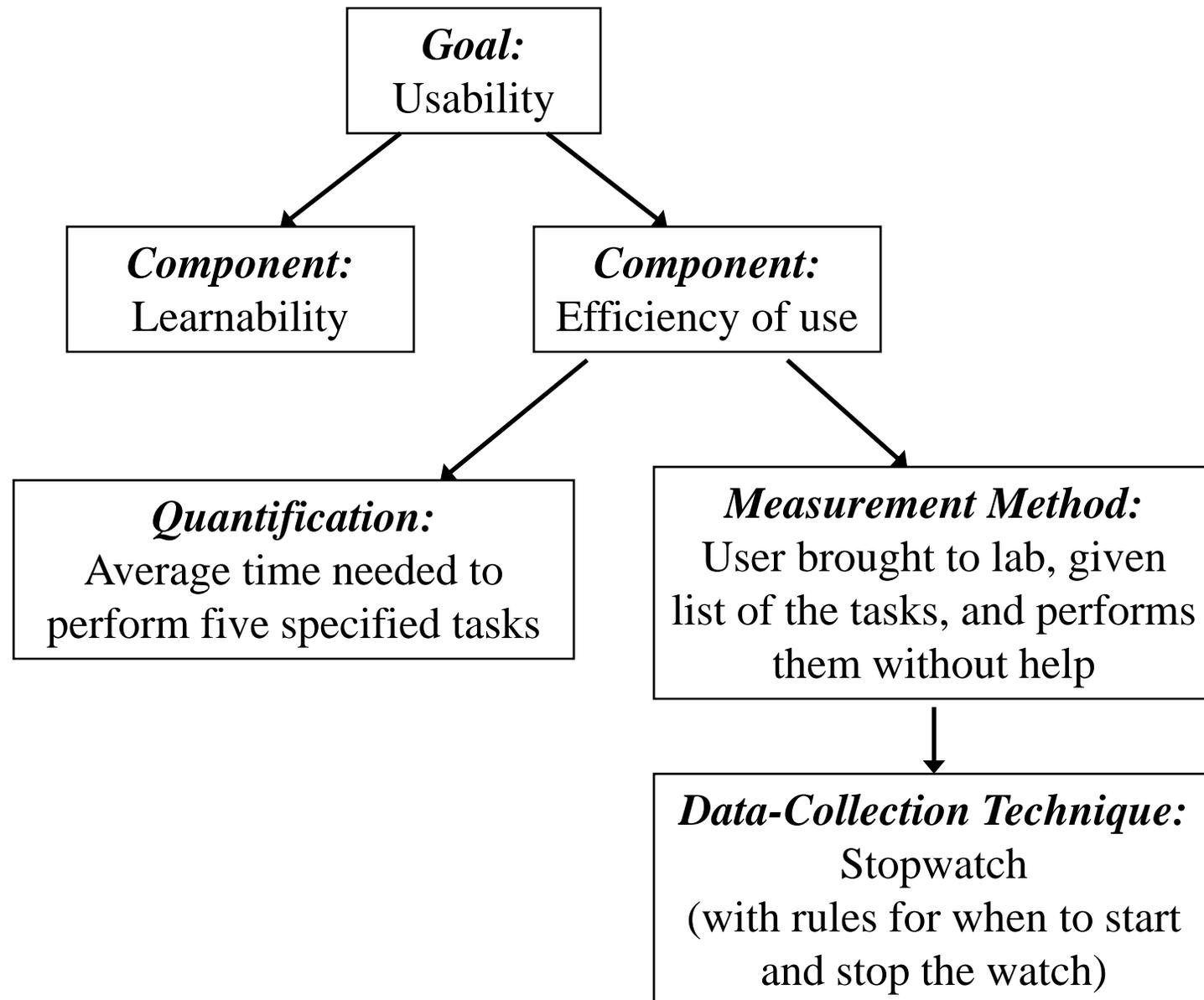

◆ **One place for guidance is NUREG 0700**

  • NUREG 0700 Human-System Interface Design Review Guidelines

    – 659 page document on design review!

  • Display formats (text; graph, charts)

  • Display elements (characters, icons, labels, colors)

  • Data Quality and update rate

  • Display pages

  • Display devices (video, projectors, meters, lights, numeric displays

  • Interface interactions (menus, cursors, what shows up where, help)

  • Alarms

  • Display customization

  • Communications/annunciations

  • Workplace/workstation design

  • ……

Usability Testing

- **Important to test usability of interface with actual people**
  - People tend to find new ways to use a product
  - Might introduce risks not obvious to designers
- **Create test plan**
  - What is the goal of test?
  - What software tools do you need?
  - What are the test tasks?
  - …
- **Perform pilot test**
  - Helps catch deficiencies in the test early
- **Identify experimenters and test users**
  - Test users should be as representative as possible of intended audience
- **Run test and measure performance**
  - Time taken, tasks completed, ratio between successful tasks and errors
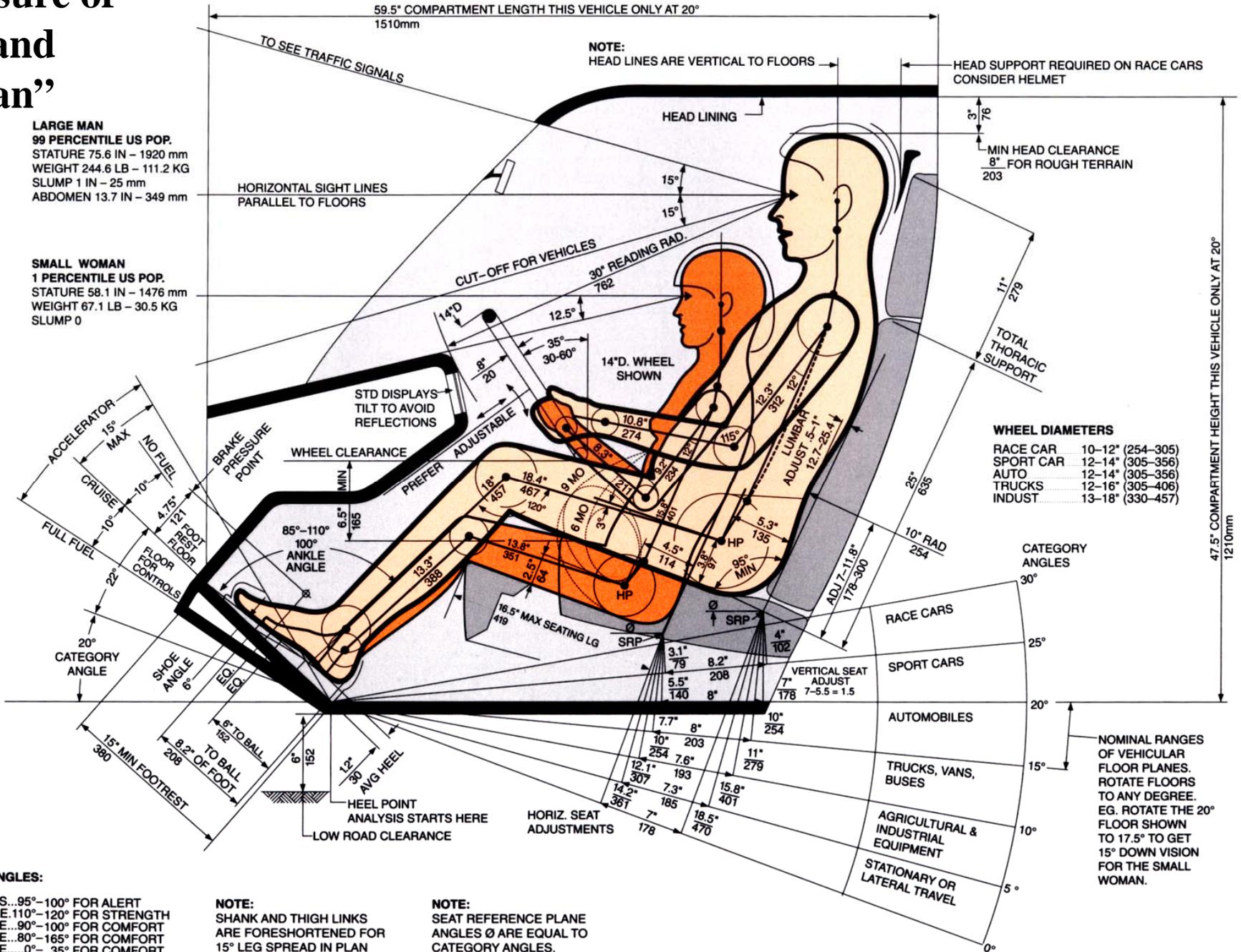
Measuring Usability [Nielsen93]

Goal:
Usability

Component:
Learnability

Component:
Efficiency of use

Quantification:
Average time needed to
perform five specified tasks

Measurement Method:
User brought to lab, given
list of the tasks, and performs
them without help

Data-Collection Technique:
Stopwatch
(with rules for when to start
and stop the watch)

"Measure of Man and Woman"

LARGE MAN
99 PERCENTILE US POP.
STATURE 75.6 IN – 1920 mm
WEIGHT 244.6 LB – 111.2 KG
SLUMP 1 IN – 25 mm
ABDOMEN 13.7 IN – 349 mm

SMALL WOMAN
1 PERCENTILE US POP.
STATURE 58.1 IN – 1476 mm
WEIGHT 67.1 LB – 30.5 KG
SLUMP 0

66

59.5" COMPARTMENT LENGTH THIS VEHICLE ONLY AT 20°
1510mm

TO SEE TRAFFIC SIGNALS

NOTE:
HEAD LINES ARE VERTICAL TO FLOORS

HEAD SUPPORT REQUIRED ON RACE CARS
CONSIDER HELMET

HEAD LINING

3"
76

MIN HEAD CLEARANCE
8" FOR ROUGH TERRAIN
203

15°

15°

HORIZONTAL SIGHT LINES
PARALLEL TO FLOORS

CUT–OFF FOR VEHICLES

30° READING RAD.
762

12.5°

14"D

35°
30-60°

11"
279

TOTAL
THORACIC
SUPPORT

14"D. WHEEL
SHOWN

STD DISPLAYS
TILT TO AVOID
REFLECTIONS

8"
20

WHEEL CLEARANCE

PREFER ADJUSTABLE

BRAKE
PRESSURE
POINT

10.8"
274

115°

12.3"
312   12°

LUMBAR
ADJUST 5-1"
12.7-25.4

25°
635

10° RAD
254

WHEEL DIAMETERS
RACE CAR .... 10–12" (254–305)
SPORT CAR ...... 12–14" (305–356)
AUTO .... 12–14" (305–356)
TRUCKS .... 12–16" (305–406)
INDUST .... 13–18" (330–457)

ACCELERATOR

15°
MAX

NO FUEL

CRUISE

10°

4.75"
121

FOOT
REST
FLOOR

FULL FUEL

10°

FLOOR
FOR
CONTROLS

22°

85°–110°
100°
ANKLE
ANGLE

6.5"
165

MIN

18"
457

18.4"
467

120°

9 MO

6 MO

13.3"
388

13.8"
351

2.5"
64

16.5" MAX SEATING LG
419

HP

5.3"
135

4.5"
114

HP

95°
MIN

ADJ 7-11.8"
178-300

20°
CATEGORY
ANGLE

SHOE
ANGLE
6°

EQ.   EQ.

6" TO BALL
152

8.2" OF FOOT
208

9"
152

12"
30

AVG HEEL

HEEL POINT
ANALYSIS STARTS HERE

LOW ROAD CLEARANCE

SRP

SRP

Ø

Ø

SRP

4"
102

3.1"
79

8.2"
208

5.5"
140   8"

VERTICAL SEAT
ADJUST
7-5.5 = 1.5

7"
178

7.7"   8"

10"
254   203

12.1"
307   7.6"
193

14.2"
361   7.3"
185

7"
178

10"
254

11"
279

15.8"
401

18.5"
470

HORIZ. SEAT
ADJUSTMENTS

**CATEGORY
ANGLES**

30°

RACE CARS

25°

SPORT CARS

20°

AUTOMOBILES

15°

TRUCKS, VANS,
BUSES

10°

AGRICULTURAL &
INDUSTRIAL
EQUIPMENT

5°

STATIONARY OR
LATERAL TRAVEL

0°

NOMINAL RANGES
OF VEHICULAR
FLOOR PLANES.
ROTATE FLOORS
TO ANY DEGREE.
EG. ROTATE THE 20°
FLOOR SHOWN
TO 17.5° TO GET
15° DOWN VISION
FOR THE SMALL
WOMAN.

47.5" COMPARTMENT HEIGHT THIS VEHICLE ONLY AT 20°
1210mm

15" MIN FOOTREST
380

COMFORT ANGLES:

SEAT ANGLES...95°–100° FOR ALERT
KNEE ANGLE.110°–120° FOR STRENGTH
ANKLE ANGLE...90°–100° FOR COMFORT
ELBOW ANGLE...80°–165° FOR COMFORT
UPPER ARM ANGLE.....0°– 35° FOR COMFORT

NOTE:
SHANK AND THIGH LINKS
ARE FORESHORTENED FOR
15° LEG SPREAD IN PLAN

NOTE:
SEAT REFERENCE PLANE
ANGLES Ø ARE EQUAL TO
CATEGORY ANGLES.
COMPARTMENTS CHANGE

BALL GRIPS

INCLUDES DIFFERENTLY ABLED

HANDS
1.25"–2"
32 51

0.5"–0.75"
13mm 19

FINGERS

HAND
2–4" CLEAR
51–102mm

FINGER
1–2" CLEAR
25.4–51mm

PREFER
WRIST
REST

LG MAX: 14" TRAVEL
356mm

6" FOR 2" TRAVEL
152 51

90°MAX
ROT.

ROT.

HAND FORCES
PULL: 5 lb (22N)
PUSH: 10 lb (44N)
MAX: 15 lb (66N)

HIGH TORQUE KNOBS

PALM GRIP OR FIVE FINGER GRASP
1.5" MIN–3" MAX
38mm–76mm

FINGER
NOTCHES
HELP

0.5" MIN–1" MAX
12.7mm–25.4

1"MIN

TORQUE: 20 lb (f)–IN (2.3 N·m)

ROTARY KNOBS

FINGER TIP GRIP/CONTINUOUS ROTATION
SIZED TO ACCOMMODATE DIFFERENTLY ABLED

POSSIBLE
SKIRT

POSSIBLE MARKINGS

POSSIBLE POINTER

KNURLING
MEDIUM
TORQUE

SMOOTH
LOW
TORQUE

SERRATED
HIGHER
TORQUE

1" to 1.5"D
25.4 38

OFF

0.5" MIN–1" MAX
13"mm 25.4

TORQUE: 0 TO 5.2 OZ (f)–IN (0.037 N·m)
KNOB SEPARATION: 2" (51mm) MINIMUM

HAND WHEELS

FOR VEHICLE, VALVES, TOOLS

7"MIN
178mm

DIAMETER

DN

UP

21" MAX
533mm

OPTIMUM
VIEWING
OF DIALS

2–4
SPOKES

RECESS
HUB FOR
SAFETY

OPTIMUM
HAND–
REST
ANGLE

30°

RIM DIA
0.75" MIN
19mm
1.125" MAX
28mm

RIM FORCE:
3–5 lb (13–22N) OPT ONE HAND
20 lb (89N) MAX ONE HAND
30 lb (133N) MAX TWO HANDS

0.75"
19mm

0.125
3

ALT

RING PULLS

FORCE
FOR SHORT
DURATION

DIAMETER

FOR
MOST
ADULTS

LB	N	IN	mm
40	178	1.0	25
20–40	89–178	0.75	19
15–20	67–89	0.50	13
0–15	67	0.25	6

MIN RING DIA

			% HAND FORCE
ONE HAND	2.75"	(70mm)	100
THREE FINGERS	2.25"	(57mm)	75
TWO FINGERS	1.5"	(38mm)	50
ONE FINGER	1.0"	(25mm)	25

FLUSH FINGER PULLS

ONE FINGER TIP

FOUR FINGER HOOK

0.7"
18

0.8"MIN DIA
20mm

0.5" MIN
13mm

1.1" MIN 1.5" OPT
28mm 38mm

MIN
1.25"
32

1.7" MIN 1.9" OPT
43mm 48mm

OPENING 3.5" MIN 4" OPT
WIDTH: 89mm 102mm

KEY PAD STANDARDS

ARM AND
WRISTREST
3" MIN
76mm

KEY SPACING BOTH WAYS

0.75"
19

0.5" SQUARE TOPS
13mm

ADJUSTABLE

6" PREFER
152mm

1"R
25

15°

5°

CUSHION
HELPS

MOVEABLE

30mm HOME ROW
VERT TRAVEL

FRONT EDGE OF TABLE

NOTE: AVOID
BENDING WRIST

TRAVEL: 0.03–0.2" (0.8–5mm)
RESISTANCE: 1–10 OZ (0.28–2.8N)

ROCKER SWITCHES

BARE GLOVE
0.75" 1.25"
19 32

1" MIN
25.4mm

2.5" MAX
64

OFF ON

ON

MIN 0.75"
19

OFF

RED

0.188"
4.8mm

MIN MAX
0.25" 1.5"
6.4 38

30°

0.125"
3.2

CAN COLOR CODE,
ILLUMINATE, ADD
TITLES AND SEE ON/OFF.

RESISTANCE:
10 OZ (2.8 N) MIN 40 OZ (11 N) MAX

TOGGLE SWITCHES

0.75" MIN
19mm

2" OPT
51mm

ON

OFF ON

OFF

GLOVES
2" MAX 1.5" MIN
51mm 38mm

1.2" MIN
32mm

2" OPT

30° MIN
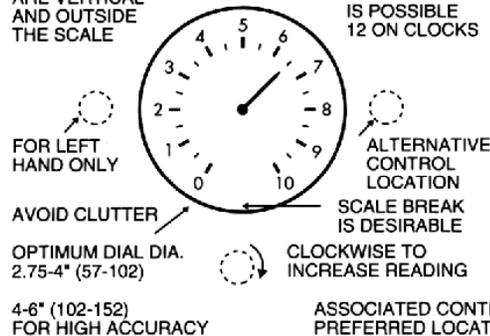60° MAX

0.5" MIN
13

0.125" MIN
3mm

1" MAX
25.4mm

RESISTANCE:
SMALL SWITCH–10 OZ (28N) MIN; 16 OZ (4.5N) MAX
LARGE SWITCH–10 OZ (28N) MIN; 40 OZ (11 N) MAX

CIRCULAR DIALS 89% EFF.

QUANTITATIVE/QUALITATIVE AND SNAP CHECK
NOS. INCREASE CLOCKWISE

ARE VERTICAL
AND OUTSIDE
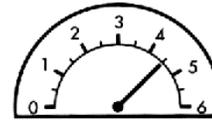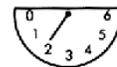THE SCALE

ZERO AT TOP
IS POSSIBLE
12 ON CLOCKS

FOR LEFT
HAND ONLY

ALTERNATIVE
CONTROL
LOCATION

AVOID CLUTTER

SCALE BREAK
IS DESIRABLE

OPTIMUM DIAL DIA.
2.75-4" (57-102)

CLOCKWISE TO
INCREASE READING

4-6" (102-152)
FOR HIGH ACCURACY

ASSOCIATED CONTROL
PREFERRED LOCATION

SEMI CIRCULAR DIALS 83% EFF.

QUANTITATIVE/QUALITATIVE AND SNAP CHECK

AVOID
MOVING
DIAL FACES

PREFER
NUMBERS
OUTSIDE
INDICES

UPSIDE DOWN
IS POSSIBLE

USE ZONES
TO SIMPLIFY
SCALE IF
POSSIBLE

GOOD FOR
ZERO CHECK
READINGS
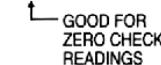
AVOID DISTRACTING LOGOS ON ALL DIAL FACES

NOS.AND SPACING OF SCALE MARKINGS
ULTIMATELY DETERMINE THE SIZE OF THE DIAL

HORIZONTAL SCALES 72% EFF.

QUANTITATIVE/QUALITATIVE AND SNAP CHECK FOR
FIXED SCALES AND MOVING POINTERS
QUANTITATIVE ONLY FOR MOVING SCALES WITH THE
POSSIBITY OF USING LONG SCALE TAPES

TITLE

0 5 10 15 20

FOR LEFT
HAND (ALT)

FOR RIGHT
HAND (ALT)

NOS INCREASE
LEFT TO RIGHT

TURN KNOB
CLOCKWISE
TO INCREASE
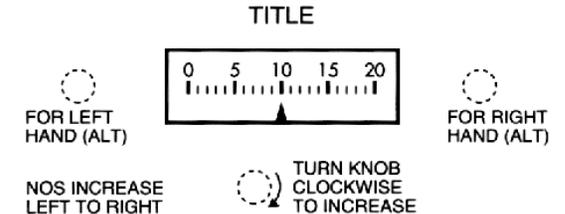
RECOMMEND FIXED SCALE AND MOVING POINTER

CHECK DIALS (FOR GROSS READINGS)

ORDER OF
SEQUENCE 1 2

NORMAL
POSITION
FOR
VERTICAL
ARRAYS

PREFER
HORIZONTAL
ARRAYS
AS SHOWN 3 4

NOS. INSIDE
INDICES ON
SMALL DIALS

1.75"DIA
45mm

OPT 0
POINTER
POSITION
FOR CHECK
READING

MIN SPACING
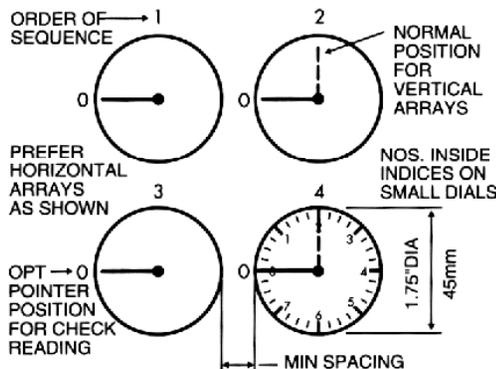
ZONE CODED DIALS

DIAL READING CAN BE SIMPLIFIED BY THE USE OF
ZONE MARKINGS IF PRECISE NUMERICAL VALUES
ARE NOT REQUIRED

EXAMPLE 1

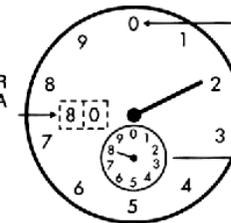EXAMPLE 2

HOT
SAFE
COLD

GREEN

YELLOW YELLOW
RED RED
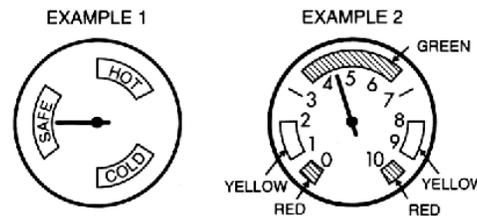
CONSIDER COLOR CODING THE ZONE MARKINGS
GREEN-SAFE, NORMAL, SATISFACTORY, DESIRABLE
YELLOW-CAUTION, WARNING
RED-DANGER, UNDESIRABLE, INEFFICIENT

MULTI-REVOLUTION DIALS

LIMIT MULTI-POINTER DIALS TO 2 HANDS

ALTERNATE:
LONG SCALE
CHECK AND
QUALITATIVE
DIAL HAS
COUNTER FOR
PRECISE DATA

ZERO
STARTS
HERE FOR
360° SCALE

SUBDIAL FOR
PRECISE
READINGS

SOME
WATCHES
HAVE FOUR
SUBDIALS EG:
DATE, DAY,
MONTH AND SEC.

1 REV EQUALS
1 INTERVAL
ON MAIN
DIAL

MULTI-POINTER DIALS ARE CONFUSING TO READ
THE COMMON ALARM CLOCK WORKS IF SWEEP HAND
IS RED AND ALARM HAND IS INCONSPICUOUS
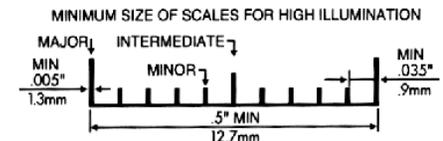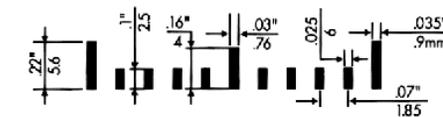
SCALES

MINIMIZE NUMBER OF MARKINGS IF NOT REQUIRED

5 RECOMMENDED SCALES:

0 5 10 15 GOOD

0 3 6 9 12 FOR TIME/
COMPASS

0 10 SUPERIOR
SCALE

0 2 4 6 FAIR

0 1 2 3 GOOD
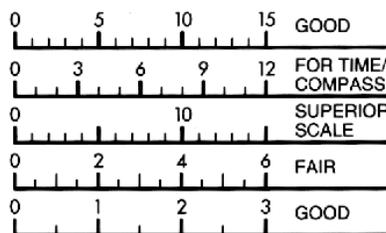
CAN ADD ZEROS OR DECIMALS TO DIGITS ABOVE
AVOID SCALES: 2.5 5 7.5 AND 4 8 12
AVOID VARIABLE SCALES EG LOGARITHMIC
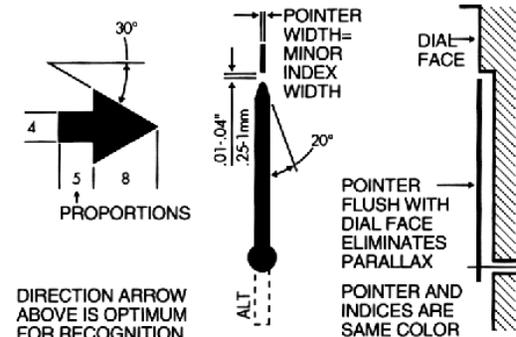AVOID MIXING DIFFERENT SCALES NEARBY

INDICES

MINIMUM SIZE SCALES FOR LOW ILLUMINATION,
VIEWING DISTANCE: 28-36" (711-914mm)

.1"
2.5

.16"
4

.03"
.76

.025

.035"
.9mm

.22"
5.6

.07"
1.85

MINIMUM SIZE OF SCALES FOR HIGH ILLUMINATION

MAJOR INTERMEDIATE

MIN
.005"
1.3mm

MINOR

MIN
.035"
.9mm

.5" MIN
12.7mm

MINIMUM SPACE BETWEEN INDICES:
2X INDEX WIDTH IF INDICES ARE WHITE ON BLACK
1X INDEX WIDTH IF INDICES ARE BLACK ON WHITE
SIZES ARE DIRECTLY PROPORTIONAL VIEWING DIST

POINTERS

30°

POINTER
WIDTH=
MINOR
INDEX
WIDTH

DIAL
FACE

4

5 8

20°

PROPORTIONS

.01-.04"
.25-1mm

POINTER
FLUSH WITH
DIAL FACE
ELIMINATES
PARALLAX

DIRECTION ARROW
ABOVE IS OPTIMUM
FOR RECOGNITION

ALT

POINTER AND
INDICES ARE
SAME COLOR

AVOID ORNATE POINTERS WHICH ARE DISTRACTING

33

Safety Symbols

◆ **ANSI Z535.2 Standard for Environmental and Facility Safety Signs**

http://www.weinigusa.com/safety/pg3.htm

Snopes Says "Stubby" Is Fictional:

Smilodon
Firmware Engineer
commented on Sep 19, 2008 10:56:44 AM

dalinaz wrote, "My 21 inch 5 hp gas lawn mower contains a warning not to try to pick the mower up and use it as a hedge trimmer. Want to bet that some idiot (now known as "Stubby") tried to do just that??"

My former boss testified in a product liability case on this exact issue. It was actually Mr. AND Mrs. "Stubby," who picked up their rotary mower on either side of its deck. The Stubby Family prevailed, as apparently the court thought a reasonable person might use a rotary mower as a hedge trimmer unless cautioned not to.

http://www.embedded.com/columns/technicalinsights/210601616?_requestid=219820

Some robot mowers use a "Swing Blade"

http://www.theregister.co.uk/2014/06/24/review_bosch_indego_robot_lawnmower/

• **Should there be a warning label saying "don't use mower as hedge trimmer?"**
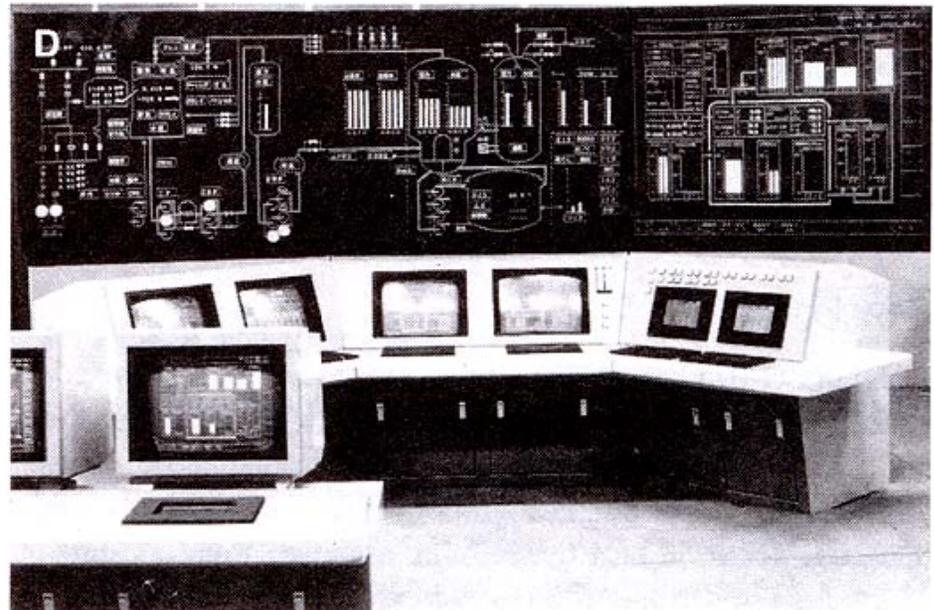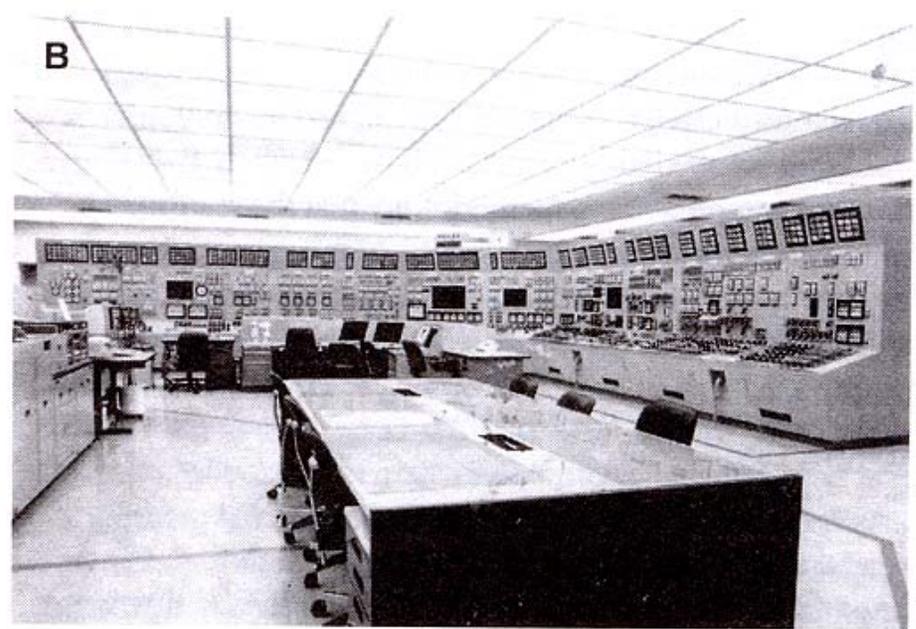
FIGURE 7-1 Evolution of Japanese nuclear power plant control rooms: (a) 1970s (Mihama-3 plant); (b) 1980s (Takahama-3 plant); (c) 1990s (Ohi-3 plant); (d) next generation plant. Source: Kansai Electric Power Co., Inc.

Submarine nuclear power plant control panel; Smithsonian exhibition

SCRAM
RUN
SCRAM

Safety
Control
Rod
Axe
Man
= SCRAM

Summary: Improving Human Performance

◆ **Practice makes perfect**

- Training is the proven way to improve performance

◆ **Avoid operator drop-out**

- Give human some (non-stressful) task that requires attention all the time
  - Example: automate vehicle speed or steering, but not both
- Inject a moderate level of drills

◆ **Strike an appropriate alarm frequency balance**

- Too many false alarms means they will be ignored
- Too few alarms means people will be unprepared and hazards may be missed

◆ **Use a well designed operator interface**

- Use anthropometric data; use psychology / cognition / perception data
- Use humans only for what they are good at
- Perform user interface studies
- Blaming the user is (usually) counter-productive in an accident investigation