Introduction to Human Factors

• “Human Factors” - what is it?
• Methodologies for understanding human activities
• Samples from past and ongoing SSL research
Subsumed within “Human Factors”

- Anthropometrics
- Bioastronautics
- Biomechanics
- Environmental medicine
- Ergonomics
- Experimental psychology
- Human engineering
- Human-machine systems design
- Human-computer interaction (HCI)
- Life sciences engineering
- ...
The Scope of Human Factors

from Chapanis, Human Factors in Systems Engineering - Wiley Interscience, 1996
Taxonomy of Human Factors Methods

- Data collection techniques
- Task analysis techniques
- Cognitive task analysis techniques
- Charting techniques
- Human error identification (HEI) techniques
- Mental workload assessment techniques
- Situational awareness measurement techniques
- Interface analysis techniques
- Systems design techniques
- Performance time prediction/assessment tech.
- Team performance analysis techniques
Data Collection Techniques

- Interviews
- Questionnaires
- Observation
Interviews

- Structured, semi-structured, unstructured
- Closed, open, and probing questions
- Focus groups instead of multiple interviews
- Interviews take the longest to train of all data collection techniques
- Should last a minimum of 20 and maximum of 40 minutes
- Data collection: notes, audio/video recorder
Questionnaires

• Types of questions used
  – Multiple choice
  – Rating scales ("strongly agree", "agree"...)
  – Paired associates ("Which is more difficult, A or B?")
  – Ranking ("On a scale of 1-10...")
  – Open-ended ("What did you think of...")
  – Closed questions ("yes/no")

• Easy to collate and reduce data
• Usually have poor voluntary response
• Needs to be designed well for best results
Analytical Hierarchy Process

• Considering a range of options, e.g., ice cream
  – Vanilla (V)
  – Peach (P)
  – Strawberry (S)
  – Chocolate (C)

• Could ask for a rank ordering, e.g. (1) vanilla, (2) strawberry, (3) peach, (4) chocolate - but that doesn’t give any information on how firm the rankings are

• Use pairwise comparisons to get numerical evaluation of the degree of preference
Pairwise Comparisons

• Ideally, do exhaustive combinations
  – Vanilla >> chocolate (strongly agree)
  – Vanilla >> peach (agree)
  – Vanilla >> strawberry (agree)
  – Peach >> chocolate (strongly agree)
  – Peach >> strawberry (disagree)
  – Strawberry >> chocolate (strongly agree)

• Number of required pairings out of N options is 
  \((N)(N-1)/2\) - e.g., \(N=20\) requires 190 pairings!

• Can use hierarchies of subgroupings to keep it manageable
Evaluation Metric

• Create a numerical scaling function, e.g.
  – “strongly agree” = 9
  – “agree” = 3
  – “neither agree nor disagree” = 1
  – “disagree” = 1/3
  – “strongly disagree” = 1/9

• Numerical rankings are arbitrary, but often follow geometric progressions
  – 9, 3, 1, 1/3, 1/9
  – 8, 4, 2, 1, 1/2, 1/4, 1/8
**Evaluation Matrix**

• Fill out matrix preferring rows over columns

<table>
<thead>
<tr>
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<th>C</th>
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<tr>
<td>V</td>
<td>9</td>
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</tbody>
</table>
### Evaluation Matrix

- Fill out matrix preferring rows over columns
- Fill opposite diagonal with reciprocals

<table>
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<tr>
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<td>V</td>
<td>9</td>
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</tbody>
</table>
Normalization of Matrix Elements

- Normalize columns by column sums

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>S</th>
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<th>V</th>
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<td>C</td>
<td>0.032</td>
<td>0.018</td>
<td>0.143</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.333</td>
<td>0.491</td>
<td>0.429</td>
<td></td>
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<tr>
<td>P</td>
<td>0.333</td>
<td>0.097</td>
<td>0.429</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>0.333</td>
<td>0.871</td>
<td>0.491</td>
<td></td>
</tr>
</tbody>
</table>

27 3.44 6.11 0.78
Evaluation of Hierarchy Among Options

- Average across the populated row elements

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>S</th>
<th>P</th>
<th>V</th>
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</thead>
<tbody>
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<td>C</td>
<td>0.032</td>
<td>0.018</td>
<td>0.143</td>
<td>0.048</td>
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<tr>
<td>S</td>
<td>0.333</td>
<td>0.491</td>
<td>0.429</td>
<td>0.313</td>
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<tr>
<td>P</td>
<td>0.333</td>
<td>0.097</td>
<td>0.429</td>
<td>0.215</td>
</tr>
<tr>
<td>V</td>
<td>0.333</td>
<td>0.871</td>
<td>0.491</td>
<td>0.424 ← Top ranking</td>
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</tbody>
</table>
## Space Allocation and Crew Flow

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
<th>% of habitable volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>Operational or Mission-related tasks</td>
<td>40%</td>
</tr>
<tr>
<td>Public</td>
<td>Dining, food, management, recreation, and exercise</td>
<td>25%</td>
</tr>
<tr>
<td>Personal</td>
<td>Sleeping, privacy, personal stowage</td>
<td>20%</td>
</tr>
<tr>
<td>Service</td>
<td>Hygiene, waste management, public stowage</td>
<td>15%</td>
</tr>
</tbody>
</table>

Data from Parker & Every (1972) and Schowalter & Malone (1972)
Analytical Hierarchy Process

- Used an Analytical Hierarchy Process survey to determine the relative importance of possible habitat functions for an MFH
  - Life support assumed present
  - Two-level AHP ranks 34 functions based on 90 pair-wise rankings

- Targeted population with experience in remote/confined environments:
  - Astronauts
  - Submariners/ship crews
    - "Submarines were found to be most similar overall to the space ship situation…"
  - Arctic/Antarctic research scientists
    - "The south pole is the closest place to space on earth where a permanent, manned US presence exists, and represents a good scientific/logistics/operations analogue for future moon/mars missions"

Source: Habitability Issues in Long-Duration Undersea and Space Missions Jul 1972

Source: Antarctic Exploration: Proxy for Safe, Sustainable Exploration of the Moon and Mars
Survey Hierarchy

Top-level matrix

Health and Hygiene
- Habitat cleanliness
- Personal hygiene
- Comfort of bathroom
- Quality of medical
- Clothing cleanliness

Communications
- Comms functions
- Comms time/day
- Comms privacy
- Connec-tion quality

General environ.
- Lighting control
- Noise control
- Windows
- Odor control
- Temp. control
- Standing clearance
- Food quality

Recreation area
- Rec. time/day
- Rec. space
- Rec. variety
- Rec. alone ratio
- EVA time/day

Exercise area
- Exe. time/day
- Exe. space
- Exe. variety
- Exe. alone ratio
- Work alone ratio

Work area
- Work time/day
- Work space
- Prep time/EVA
- Sleep privacy
- Sleep comfort
- No hot-racking

Sleep area
- Sleep time/day
- Sleep space
Online AHP Survey

Minimal Lunar Habitat Survey

Preliminary Questions

Introduction

This is a University of Maryland functioning lunar habitat. Your responses are anonymous and are intended for research purposes.

Scenario

You are to live in a confined, self-sustaining, closed loop environment with some limited ability to leave the habitat for brief periods of time. The activities below are functions that the habitat could perform, but the habitat must additionally provide you with some level of additional support. Please answer the questions below to the best of your ability.

Instructions

You will be asked to rank the features of the habitat into eight sections. For each pairing of features, a statement in parentheses represents the level of importance of one feature over the other in different pairings. Some sections may be scored by you only once, and some by multiple times. Please use your best estimate.

1. What type of confined environment do you prefer?
   - Antartica
   - Moon
   - Mars

2. How much experience do you have in working with closed loop environments?
   - < 1 month
   - 1 to 6 months
   - 7 to 12 months
   - > 12 months

3. What is your age?
   - 22

4. What is your gender?
   - Male
   - Female

5. What is your Nationality?
   - American

Main Questions

Top Level Features

1. How many hours per day would you like to spend working (including mission related tasks) inside the habitat?

2. How many hours per day would you like to spend working outside the habitat?

Keeping in mind that your basic life support needs will be met, evaluate the relative importance of the following features:

Feature 1
- Quality of External Environment
- Quality of Habitat Environment
- Amount of Work Time / Day
- Experiences from Habitat
- Amount of Work Time / Day

Feature 2
- Health & Hygiene
- Quality of External Environment
- Health & Hygiene
- Quality of Habitat Environment
- Health & Hygiene
- Amount of Work Time / Day

Feature 3
- Food & Water
- Quality of External Environment
- Health & Hygiene
- Quality of Habitat Environment
- Health & Hygiene
- Amount of Work Time / Day

Feature 4
- Space Systems
- Quality of External Environment
- Health & Hygiene
- Quality of Habitat Environment
- Health & Hygiene
- Amount of Work Time / Day

Feature 5
- Mission Success
- Quality of External Environment
- Health & Hygiene
- Quality of Habitat Environment
- Health & Hygiene
- Amount of Work Time / Day

Feature 6
- Safety
- Quality of External Environment
- Health & Hygiene
- Quality of Habitat Environment
- Health & Hygiene
- Amount of Work Time / Day

Feature 7
- Comfort
- Quality of External Environment
- Health & Hygiene
- Quality of Habitat Environment
- Health & Hygiene
- Amount of Work Time / Day

Feature 8
- Communication
- Quality of External Environment
- Health & Hygiene
- Quality of Habitat Environment
- Health & Hygiene
- Amount of Work Time / Day
Data Analysis Method

• Subjective survey responses converted to numerical relative importance values and fed into AHP matrices:
  “Much less important” = 0.125 ( = 2^{-3} )
  “Moderately less important” = 0.354 ( = 2^{-1.5} )
  “A little less important” = 0.707 ( = 2^{-0.5} )
  “About as important” = 1.000 ( = 2^{0} )
  “A little more important” = 1.414 ( = 2^{0.5} )
  “Moderately more important” = 2.828 ( = 2^{1.5} )
  “Much more important” = 8.000 ( = 2^{3} )

• Remaining matrix elements filled in with reciprocals of conjugate elements

• For each AHP matrix:
  – Importance values of each function or sub-category are the elements of the normalized principal eigenvector
  – “Consistency” is matrix size divided by the principal eigenvalue, with a value of 1 indicating complete consistency
  – Function importance values multiplied by importance value of the sub-category

• Overall importance values are the averaged values generated from all respondents, weighted by matrix consistency
AHP Results: Function Importance Values

Habitat functions

1. No hot racking
2. Quality of medical
3. Quality of comms
4. Personal hygiene
5. Work time/day
6. Work space
7. Sleep comfort
8. Prep time/EVA
9. Comms functions
10. Comms privacy
11. Cleanliness of habitat
12. Comfort of bathroom
13. Comms time/day
14. Sleep privacy
15. Food quality
16. Exercise variety
17. Cleanliness of clothing
18. Work alone ratio
19. Sleep time/day
20. Exercise space
21. Temperature control
22. Exercise time/day
23. Sleep space
24. Standing clearance
25. EVA time/day
26. Odor control
27. Exercise alone ratio
28. Noise control
29. Recreation space
29. Recreation variety
30. Recreation alone ratio
31. Recreation time/day
32. Lights control
33. Windows
AHP Results: Important Functions

- Hot racking considered unacceptable, the most important function at 2.3 times the average importance value
- Medical facilities, communications connection quality, and personal hygiene round out vital functions
- Work time and space were highly ranked
- Non-physical recreation features considered especially unimportant
- Lighting quality and windows were the least important functions considered, with windows 0.35 times as important as the average function
- The most important function was 6.5 times as important as the least important function
AHP Results: Consistency and Variation

- Overall matrix consistency: 92.5%
  - Most consistent matrix: “Work space”, at 96.6%
  - Least consistent matrix: “General environmental quality”, at 90.3%
  - Importance value averages are weighted by matrix consistency to improve reliability of results

- Standard deviation and coefficient of variation were computed for each habitat function
  - Average standard deviation was 0.0215, average coefficient of variation was 73.4%
    - Greatest std. dev.: “No hot racking” ($\sigma = .0645$, $c_v = 97.4\%$)
    - Greatest coeff. of variation: “Quality of comms” ($\sigma = .0637$, $c_v = 112.5\%$)
    - Lowest std. dev.: “Recreation time per day” ($\sigma = .0066$, $c_v = 45.5\%$)
AHP Results: Consistency

- Matrix size divided by principal eigenvalue is a measure of internal consistency, ranging from zero to one
  - Overall matrix consistency: 92.5%
  - Most consistent matrix: “Work space”, at 96.6%
  - Least consistent matrix: “General environmental quality”, at 90.3%

- Importance value averages are weighted by matrix consistency to improve reliability of results
  - Mean difference from un-weighted average: 1.7%
  - Greatest difference: recreation alone-time ratio (3.9% more important in weighted average)
AHP: Demographics and Analysis of Variance

- Respondents:
  - By nationality:
    - American (15)
    - Italian (11)
    - French (2)
    - Romanian (1)
  - By experience:
    - Submarine (19)
    - Ship (11)
    - Arctic/Antarctic base (3)
    - Other (2)
  - By age group:
    - ≤40 years (16)
    - >40 years (13)
  - Performing ANOVA between astronaut and analogue populations can justify the statistical relevance of analogue populations

<table>
<thead>
<tr>
<th>Demographic set</th>
<th>Feature</th>
<th>Difference from complimentary set</th>
</tr>
</thead>
<tbody>
<tr>
<td>French</td>
<td>EVA time/day</td>
<td>+26.3%</td>
</tr>
<tr>
<td></td>
<td>Exercise alone ratio</td>
<td>-11.9%</td>
</tr>
<tr>
<td>American</td>
<td>Quality of comms</td>
<td>-5.3%</td>
</tr>
<tr>
<td>Ship crew members</td>
<td>Personal hygiene</td>
<td>+0.9%</td>
</tr>
<tr>
<td></td>
<td>Quality of medical</td>
<td>+1.3%</td>
</tr>
<tr>
<td></td>
<td>Recreation alone-time ratio</td>
<td>-0.8%</td>
</tr>
<tr>
<td></td>
<td>Sleep privacy</td>
<td>+0.3%</td>
</tr>
<tr>
<td>Submariners</td>
<td>Bathroom comfort</td>
<td>-0.6%</td>
</tr>
<tr>
<td>Age 40+</td>
<td>Comms privacy</td>
<td>-1.4%</td>
</tr>
<tr>
<td></td>
<td>Temperature control</td>
<td>-0.8%</td>
</tr>
</tbody>
</table>
Fidelity of Analogue Environments

• The analogue environments considered in the survey may be of low fidelity, due to several factors:
  – Windows may be less important in environments with a static view/no external view
  – Affects of reduced gravity on the importance of habitat functions not accounted for
  – Ability to leave environment may impact importance of habitat functions

• Larger samples and samples of the astronaut population would be needed to identify statistical significance of variations between analogue and space environments
Observation

- Provides “real-life” insight into actual operations
- Intrusive (Heisenberg’s principle)
  - “fly on wall”
  - “hanging over the shoulder”
- Time consuming (1 hr of audio = 8 hrs of transcription)
- Difficult to set up, expensive, time consuming
- Generally requires teams to cover all critical areas
Task Analysis Techniques

- Hierarchical Task Analysis (HTA)
- Critical Path Analysis (CPA)
- Goals, Operators, and Selection Methods (GOMS)
- Verbal Protocol Analysis (VPA)
- Task Decomposition
- Sub Goal Template (SGT) approach
- Tabular Task Analysis
Hierarchical Task Analysis (HTA)

- Ubiquitous; perhaps most common TA method
- Easy to implement; minimal training
- Generic; can be applied to any domain at any desired level of depth
- Descriptive rather than analytical
- Laborious for complex domain tasks
- Simple flowcharting/outlining processes
HTA Graphical Example

from Stanton et.al., Human Factors Methods - Ashgate, 2005
## HTA Tabular Example

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. Boil kettle</td>
<td>Plan 0: Do 1 then 2 then 3 then 4 then 5</td>
</tr>
<tr>
<td>1. Fill kettle</td>
<td>Plan 1: Do 1 then 2 then 3 (if full then 4 else 3) then 5</td>
</tr>
</tbody>
</table>
| | - Take to tap  
| | - Turn on water  
| | - Check level  
| | - Turn off water  
| | - Take to socket  |
| 2. Switch kettle on | Plan 2: Do 1 then 2 |
| | - 2.1 Plug into socket  
| | - 2.2 Turn on power  |
| 3. Check water in kettle | |
| 4. Switch kettle off | |
| 5. Pour water | Plan 5: Do 1 then 2 then 3 |
| | - 5.1 Lift kettle  
| | - 5.2 Direct spout  
| | - 5.3 Tilt kettle  
| | - 5.4 Replace kettle  |

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*from Stanton et. al., Human Factors Methods - Ashgate, 2005*
Cognitive Task Analysis Techniques

- Applied Cognitive Task Analysis (ACTA)
- Cognitive Walkthrough
- Critical Decision Method (CDM)
- Critical Incident Technique
Cognitive Walkthrough

• Select tasks to be analyzed
• Create task descriptions
• Determine the correct sequence of actions
• Identify the user population
• Describe the user’s initial goals
• Analyze the interaction between the user and the interfaces
  – Problems in selecting and evaluating an action
  – Changing goals due to execution and system response
Charting Techniques

• Process Charts
• Operational Sequence Diagrams
• Decision Action Diagram (DAD)
• Event Tree Analysis
• Fault Tree Analysis
• Murphy Diagrams
**Event Tree Diagram**

from Stanton et.al., Human Factors Methods - Ashgate, 2005
Fault Tree Analysis

from Stanton et al., Human Factors Methods - Ashgate, 2005
Human Error Identification Techniques

- Cognitive Reliability Error Analysis Method (CREAM)
- Human Error Assessment and Reduction Technique (HEART)
- Human Error Identification in Systems Tool (HEIST)
- Human Error Template (HET)
- Human Error HAZOP
- Systematic Human Error Reduction and Prediction Approach (SHERPA)
HEI Techniques (continued)

• System for Predictive Error Analysis and Reduction (SPEAR)
• Task Analysis For Error Identification (TAFEI)
• Technique for Human Error Assessment (THEA)
• The HERA Framework
• Technique for the Retrospective and Predictive Analysis of Cognitive Errors in Air Traffic Control (TRACEr)
Human Error Template (HET)

- Standard taxonomy of errors
  - Failed to execute
  - Task execution incomplete
  - Task executed in wrong direction
  - Wrong task executed
  - Task repeated
  - Task executed on wrong component
  - Task executed too early/late/much/little
  - Misread information

- Apply and evaluate to each bottom-level task from HTA

- Consider consequence, criticality, interface role
Situational Awareness Measurements

- SA Requirements Analysis
- Situation Awareness Global Assessment Tech.
- Situation Awareness Rating Technique
- SA Subjective Workload Dominance Metric
- Situation Awareness Control Room Inventory
- Situation Awareness Rating Scales (SARS)
- Situation-Present Assessment Method (SPAM)
- SA Behavioral Rating Scales
- Mission Awareness Rating Scale (MARS)
- Crew Awareness Rating Scale (CARS)
Situational Awareness Rating Scales

• List of 31 criteria in 8 categories from ACM SA
  – General traits
  – Tactical game plan
  – System operation
  – Communication
  – Information interpretation
  – Tactical employment BVR
  – Tactical employment visual
  – Tactical employment general

• Each criteria self-rated on 1(poor)-6(best) scale
Mental Workload Assessment

- Primary Task Performance Measures
- Secondary Task Performance Measures
- Bedford Scale
- Defense Research Agency Workload Scale
- Instantaneous Self Assessment Workload
- Malvern Capacity Estimate
- Modified Cooper-Harper Rating
- NASA Task Load Index
- Subjective Workload Assessment Technique
- Workload Profile Technique
- Cognitive Task Load Analysis
NASA Task Load Index (TLX)

- Subjective assessment on 6 scales
  - Mental demand
  - Physical demand
  - Temporal demand
  - Effort
  - Performance
  - Frustration level
  - Rating from 1 (low) to 5 (high)

- 15 pairwise comparisons for assessment of relative importance of scales

- Final score is weighted average of scale values
NASA Task Load Index

Hart and Staveland’s NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

- **Name**
- **Task**
- **Date**

**Mental Demand**

How mentally demanding was the task?

- **Very Low**
- **Very High**

**Physical Demand**

How physically demanding was the task?

- **Very Low**
- **Very High**
NASA Task Load Index (continued)

Temporal Demand

How hurried or rushed was the pace of the task?

Very Low

Performance

How successful were you in accomplishing what you were asked to do?

Perfect

Failure

Effort

How hard did you have to work to accomplish your level of performance?

Very Low

Frustration

How insecure, discouraged, irritated, stressed, and annoyed were you?

Very Low

Very High

Very High
Four Designated Exploration Sites
EVA Walking Traverse
Approaching Science Site
Night Geology Exploration with Suit Lights
# Cooper-Harper Assessment Results

<table>
<thead>
<tr>
<th>Subject</th>
<th>Shirtsleeve</th>
<th>EVA/Walking</th>
<th>EVA/Rover</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>4</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>5</td>
</tr>
<tr>
<td>Average</td>
<td>1</td>
<td>3.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0</td>
<td>0.58</td>
<td>0.82</td>
</tr>
</tbody>
</table>
NASA Task Load Index (TLX) Results

The graph compares the NASA Task Load Index (TLX) results for different conditions:

- **Mental**: Shirtsleeve vs. Suit/Walking vs. Suit/Rover vs. Night Test
- **Physical**: Shirtsleeve vs. Suit/Walking vs. Suit/Rover vs. Night Test
- **Temporal**: Shirtsleeve vs. Suit/Walking vs. Suit/Rover vs. Night Test
- **Performance**: Shirtsleeve vs. Suit/Walking vs. Suit/Rover vs. Night Test
- **Effort**: Shirtsleeve vs. Suit/Walking vs. Suit/Rover vs. Night Test
- **Frustration**: Shirtsleeve vs. Suit/Walking vs. Suit/Rover vs. Night Test

The graph shows the comparison of these conditions across different parameters, with different conditions represented by different colors and error bars indicating variability.
Team Techniques

- Behavioral Observation Scales
- Comms Usage Diagram
- Coordination Demands Analysis
- Team Decision Requirement Exercise
- Social Network Analysis
- Team Cognitive Task Analysis
- Team Communications Analysis
- Team Task Analysis
- Team Workload Assessment
- Task and Training Requirements Methodology
Team Workload Assessment

- Builds off of NASA TLX technique
- Team performs mission/run/sortie/simulation
- Individuals fill out NASA TLX
- Group fills out TLX as a team, from point of view of team
- Compare ratings between individuals, and between individuals and team
- Best indicator has been shown to be rating of poorest-performing individual
Interface Analysis Techniques

- Checklists
- Heuristics
- Interface Surveys
- Layout Analysis
- Link Analysis
- Questionnaire for User Interface Satisfaction
- Repertory Grids
- Software Usability Measurement Inventory
- System Usability Scale
- User Trials
- Walkthrough Analysis
Walkthrough Analysis

- Experienced system operators perform “walkthrough” of system under consideration
- Subject (pretends to) perform each required action, explaining function of each control and display used
- Analyst(s) can halt walkthrough and ask questions at any point
- Highly useful in early stages of development
- Highly useful for teams of operators
- Requires experienced operator(s)
System Design Techniques

- Allocation of Functions Analysis
- Focus Groups
- Groupware Task Analysis
- Mission Analysis
- Scenario Based Design
- Task Centered System Design
Scenario Based Design

• Create a series of operating scenarios for systems
• Use Walkthrough Analysis approach to “simulate” actions of experienced operators
• Determine actions, possible outcomes, design modifications to improve results
• Many potential scenarios need to be created and “played out”
• Only as good as experts and scenario designers
Performance Time Assessment Techniques

- Keystroke Level Method
- Timeline Analysis
- Critical Path Analysis
Timeline Analysis

- Collect operating timeline data wherever possible
- Perform HTA on system
- Link performance time estimates to bottom-level HTA goals
- Construct a timeline graph of nominal and off-nominal performance of mission
- Workload analysis maps directly into timelines
- Predictive performance depends on error-free execution
References

• Neville A. Stanton, P. M. Salmon, G. H. Walker, C. Baber, and D. P. Jenkins, Human Factors Methods: A Practical Guide for Engineering and Design - Ashgate, 2005

• Alphonse Chapanis, Human Factors in Systems Engineering - Wiley Interscience, 1996