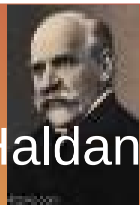

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IEHF 2011

Structuring the Analysis of Human Concerns at an Early Stage of System Development

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Background

- Critical to the effectiveness of a wide range of complex systems is successful integration with the crew
- Formal process in Ministry of Defence (MOD) is Human Factors Integration (HFI)
- Developed over many years — details can be found on open MOD web site & elsewhere
- Key element conducted at early stage of system development is Early Human Factors Analysis (EHFA)
- Intended to identify important HFI concerns that may need to be addressed during the development process
- Adopts widely applied risk analysis practice of rating both probability of occurrence and impact as Low/Medium/High — recorded in a risk register
- Progress with important concerns should be tracked as the system evolves

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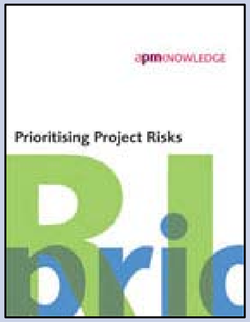
Motivation

- Risk Analysis community has been reviewing approaches to project risk analysis
- Association for Project Management pamphlet (2008) argues that standard Probability/Impact table does not provide a useful basis for risk management
- Risks that are not independent are treated as if they are — can be misleading
- Proposed treating positive and negative outcomes on the same footing by analysis of chains of cause and effect
- Reduces the number of nominally independent ‘risks’ to be tracked; provides more detailed insight into how the effects arise
- Makes explicit any implicit models underlying subjective estimates of probability and impact; underlying assumptions can be properly reviewed



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Development of extended approach to EHFA

- Aim: define a robust scientific approach to determine the impact of technology on humans
  - can be applied to both a technology without a defined application and a specific system development

- Requirements — methodology should:
  - use modern approaches to risk assessment
  - establish connection between positive/negative human impacts and military capability
  - be practicable for those involved in procurement

- Initial prototype developed; tested with a series of case studies; method modified as a result of tests

- Evolved a five-step process

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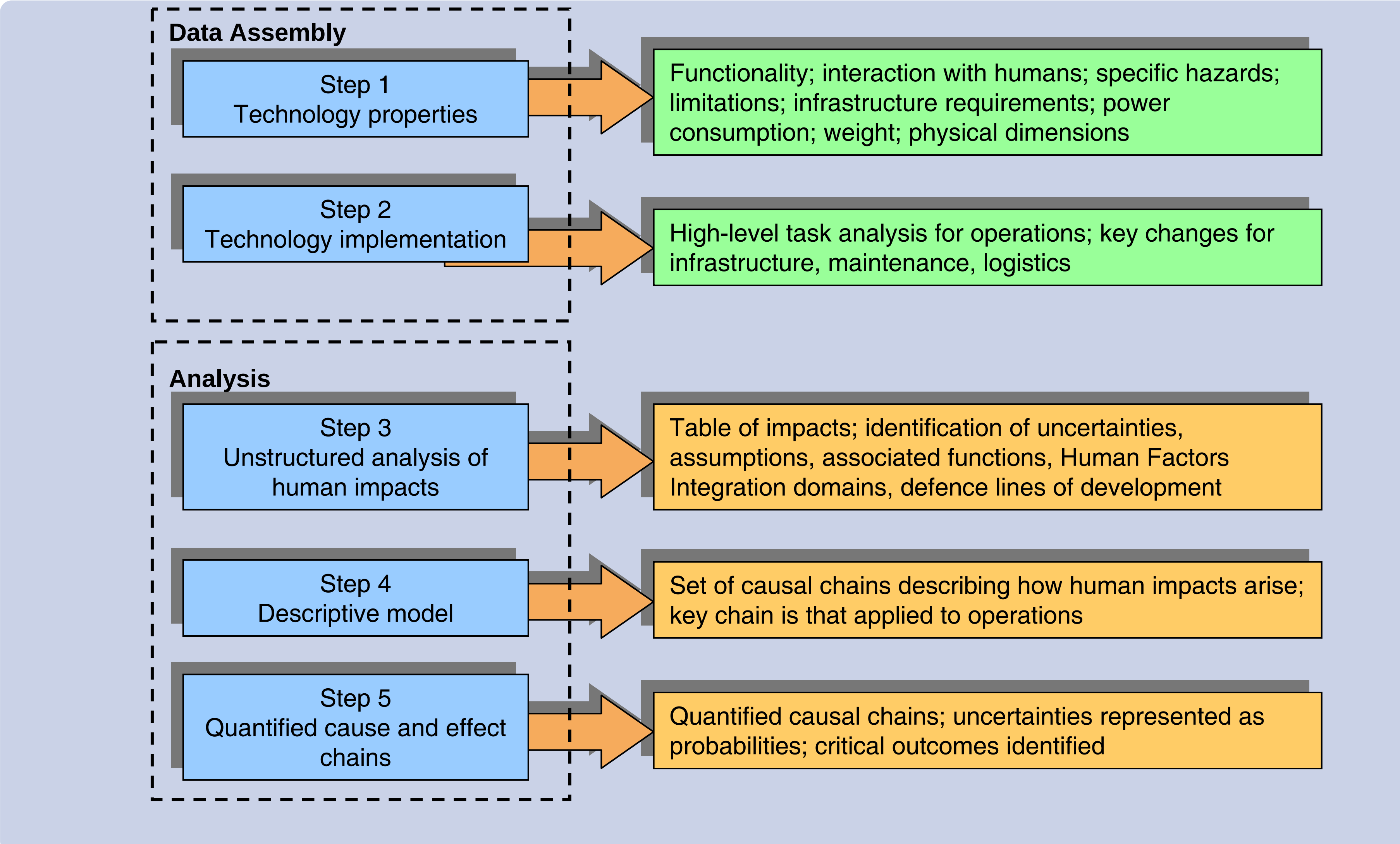
Structure of the methodology



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Technology properties

1. Functionality
2. How used by humans
3. Size and power needs
4. Technology Readiness Level
5. Support infrastructure needs
6. Existing capability being replaced, and reasons
7. Human–Machine Interaction (HMI) category:
    - portable to cockpits to complete platforms
8. Human channels utilised:
    - visual, auditory, tactile, olfactory, taste, cognitive, psychomotor, direct to brain
9. Hazards (in use, maintenance, disposal)

- Minimum set – other properties may emerge at this step or in Step 2 (derivation of Use Cases)
- Definition of HMI category & channels may form part of Use Case (application) rather than technology

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Video-inpainting

- Technology that can be used to manipulate video images
- Applies to both still images and video clips
- Analysis of image using software can remove objects and fill in background in a convincing manner
- Key application in example is as training tool — elements exaggerated by removing overlying objects

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Sample properties for video-inpainting

Property	Function	Notes
Functionality	Process short video clips for use in training	Can be used offline to remove obscuring items from a video clip and enhance the image slower than real time
How it is used	Through software on a computer	
Predicted limitations	Process video clips	Time consuming for high resolution clips at high frame rates (25 frames per second)
Infrastructure requirements	Process video clips	A computer with the software installed
Weight	Process video clips	Standard computer weight
Physical dimensions	Process video clips	Standard computer dimensions
Technology Readiness Level [5]	Process video clips	Offline processing – TRL 6

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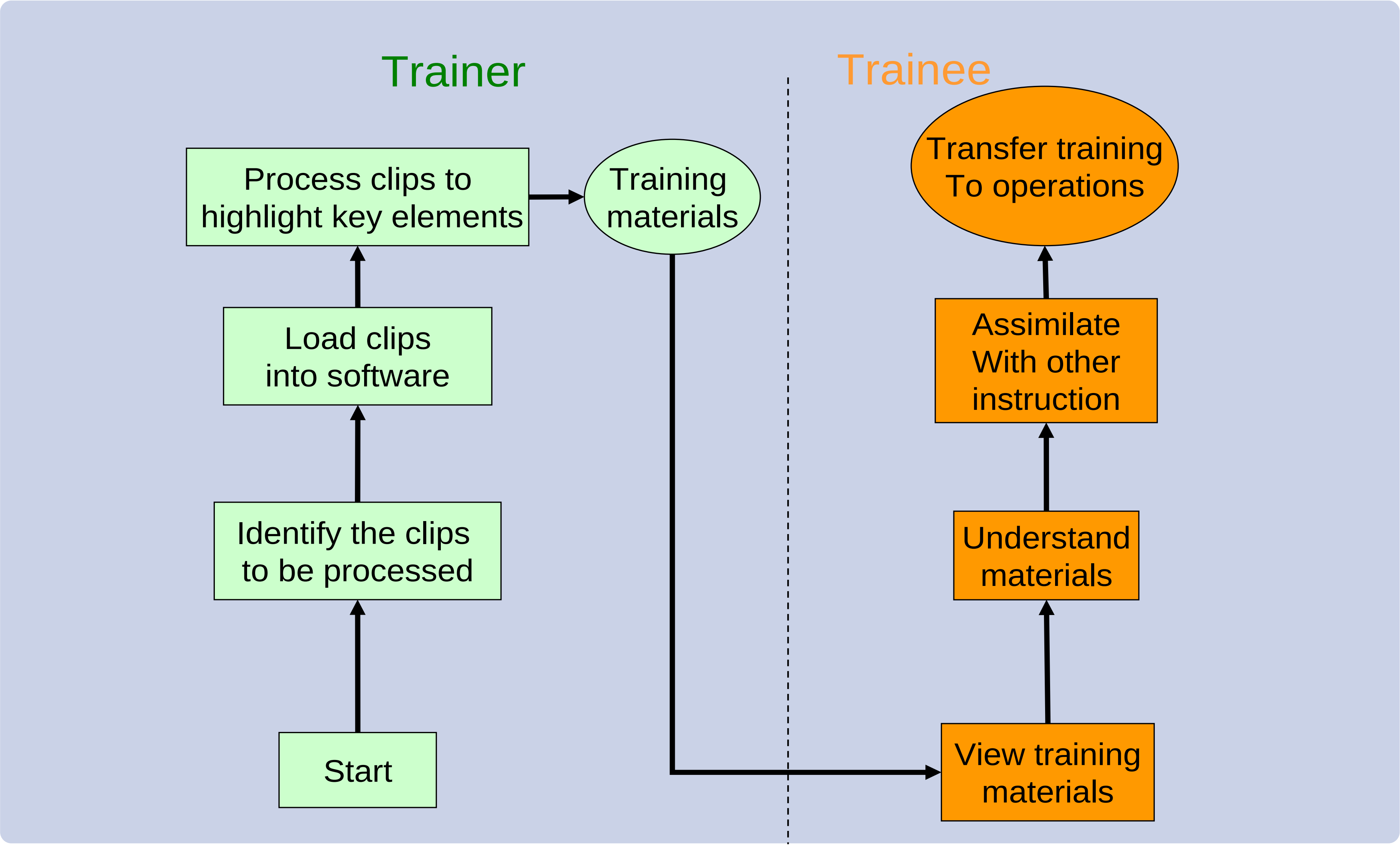
Application of video-inpainting to training



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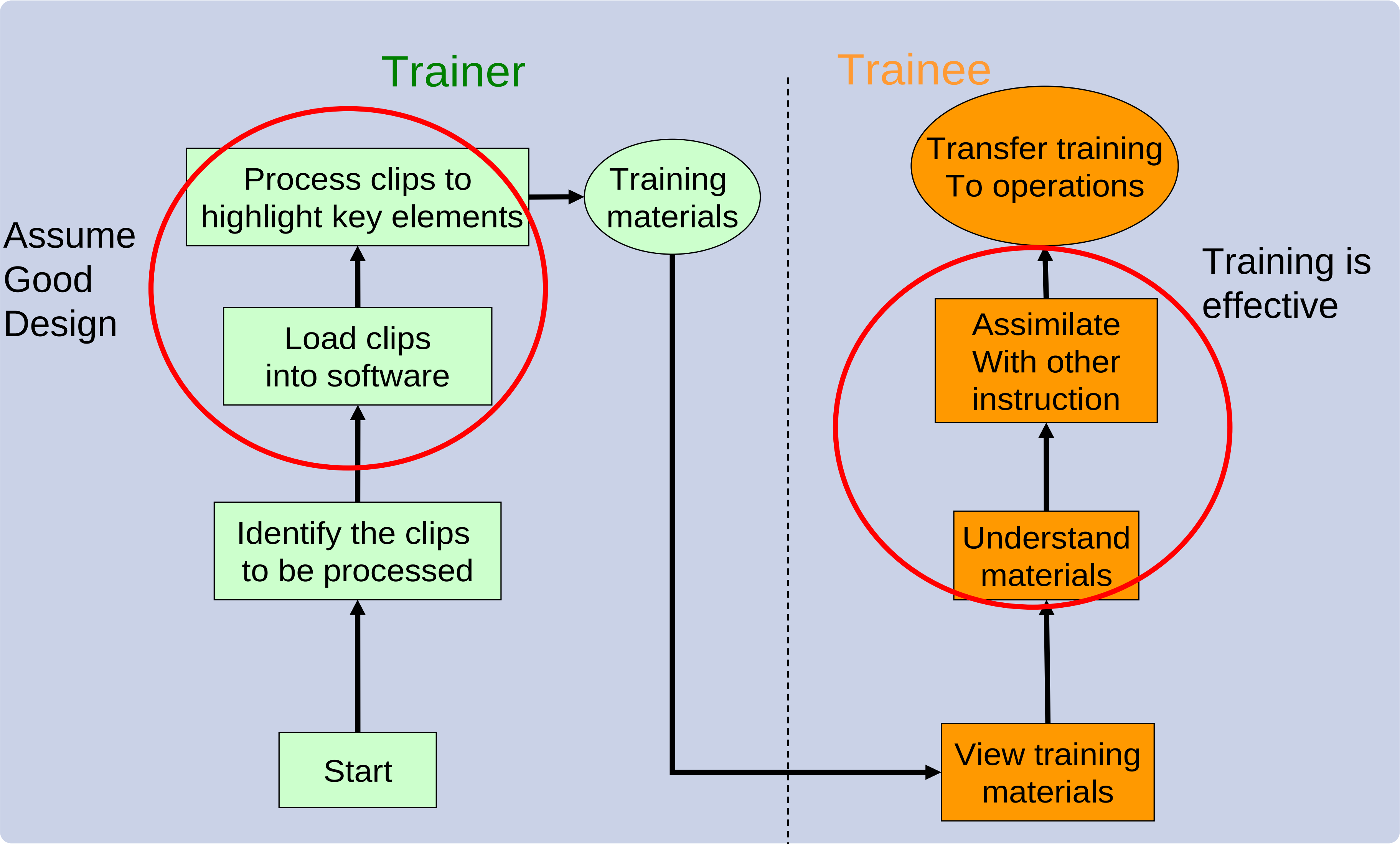
Unstructured analysis – key concerns



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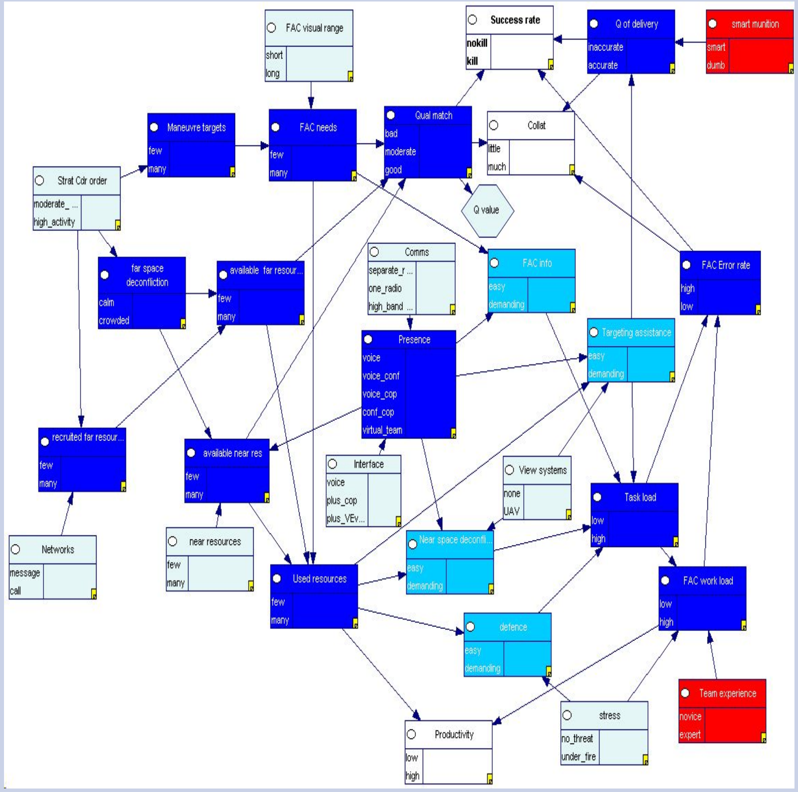
Causal chains

- Number of methods of developing causal chains considered
- Desire to be able to go directly from descriptive network to quantified network
- Agreed that Bayesian Belief Network a good approach
- Employed the GeNIe software (Decision Systems Laboratory, University of Pittsburgh) http://genie.sis.pitt.edu/
- Programs available in compiled form, free of charge for any use (includes explicitly potential commercial use)
- Constructed causal chains describe effects flow for video-inpainting



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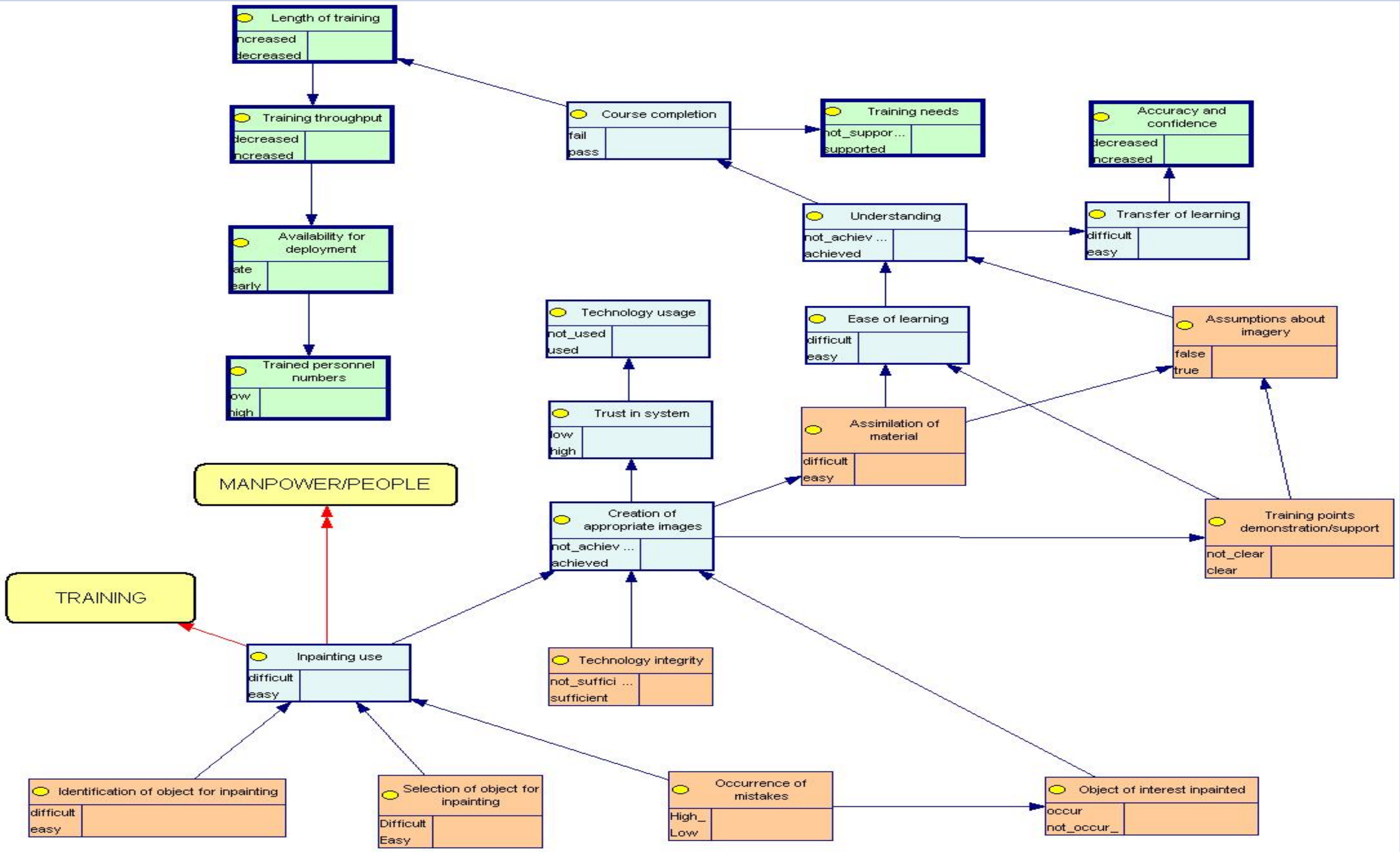
Video inpainting causal chain



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Quantification

- Key element in quantification is setting conditional probabilities for node outcomes conditional on set of inputs
- Was suggested that seven-point scale more than adequate: 0, 0.1, 0.3, 0.5, 0.7, 0.9, 1
- 0 and 1 endpoints useful: ‘certainly not’ and ‘certainly’ can be used to test specific paths in the tree
- In practice, shorter scale (such as 0, 0.25, 0.5, 0.75, 1) often as effective
- Sample shown for ‘Creation of appropriate images’ node

Technology integrity:	**Not sufficient**				**Sufficient**			
Object of interest inpainted:	**Occur**		**Not Occur**		**occur**		**Not Occur**	
Inpainting use:	**Diff.**	**Easy**	**Diff.**	**Easy**	**Diff.**	**Easy**	**Diff.**	**Easy**
Not achieved	0.9	0.9	0.9	0.7	0.9	0.5	0.3	0.1
Achieved	0.1	0.1	0.1	0.3	0.1	0.5	0.7	0.9

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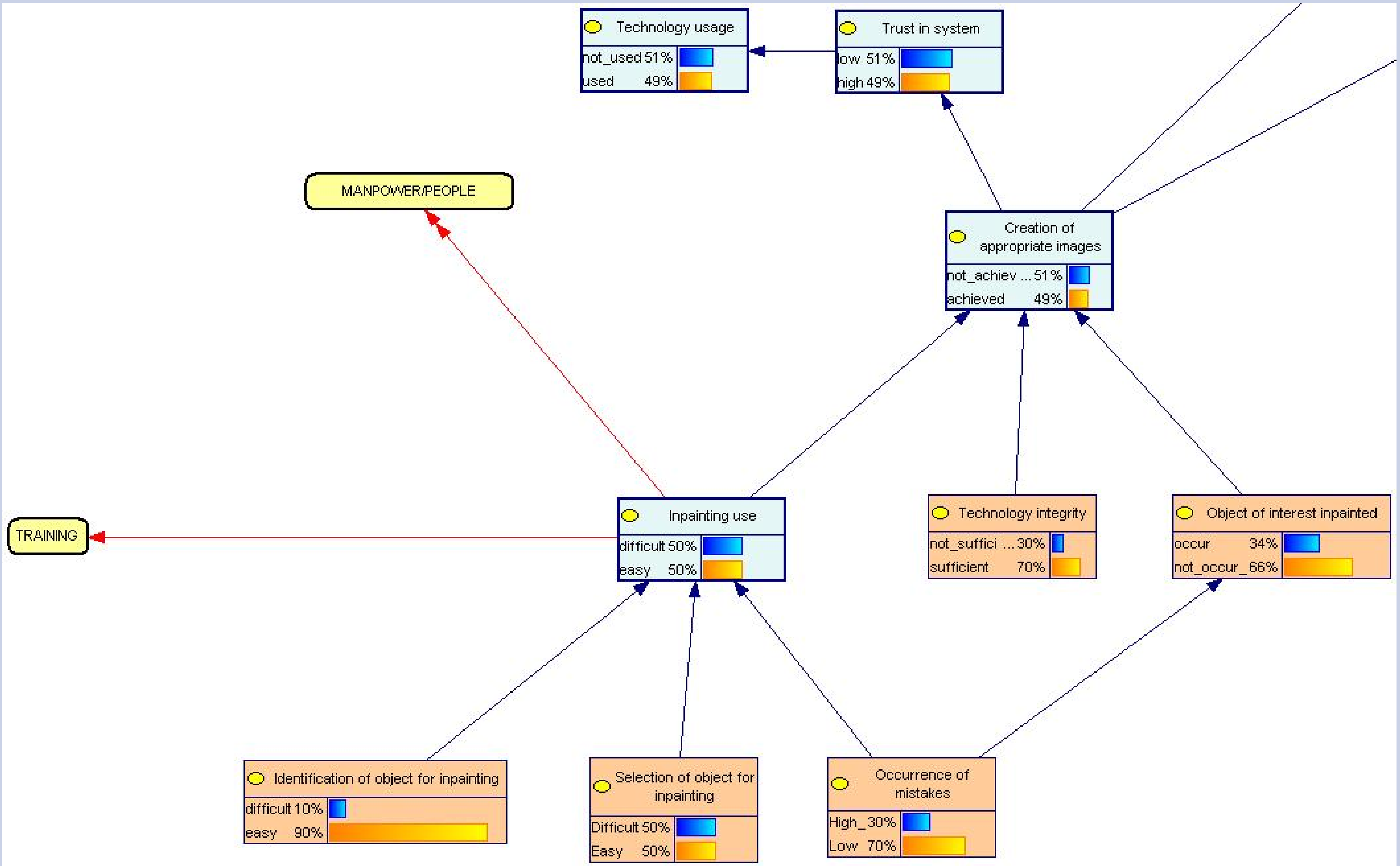
Video-inpainting sample



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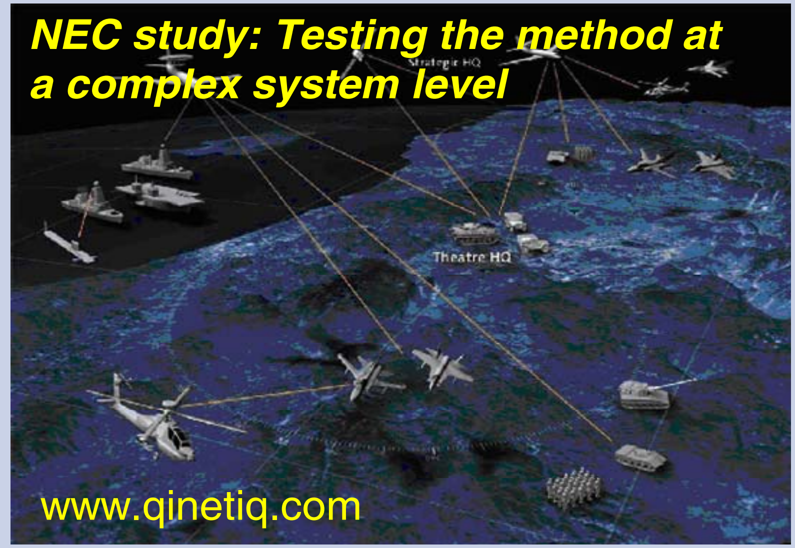
Tested on a range of technologies

- Range of technologies studied during development of methodology; was found that it was possible to apply the approach
- Ranged from performance modification of individuals to small team application to more sophisticated applications
  - Video-inpainting
  - Hand cooling glove
  - Slow wave sleep stimulation
  - Through the wall 2-D radar
  - Soldier modernisation
  - Network Enabled capability example
- In all cases, found it possible to apply the approach



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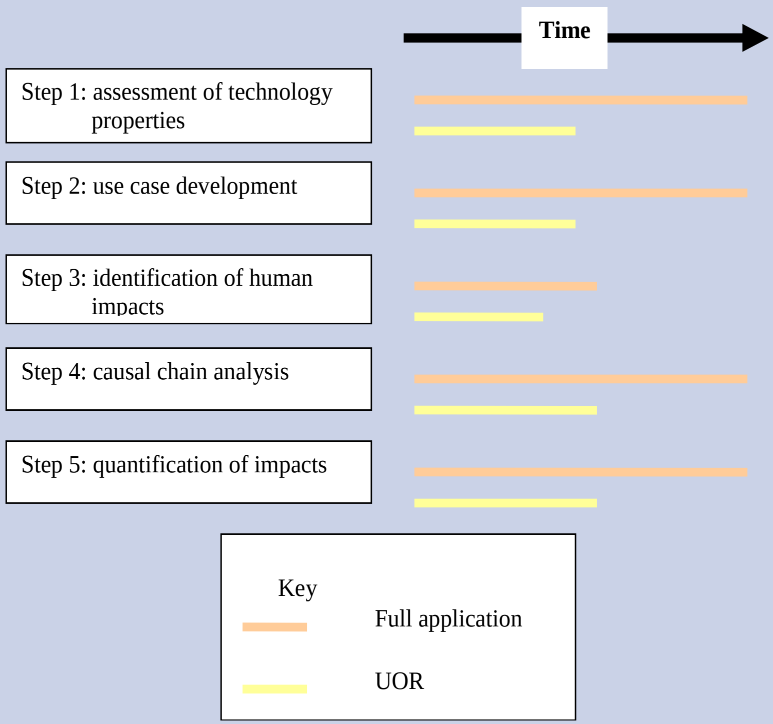
Key findings for the methodology

- Possible to quantify the military impact from the relationship and quantification of positive and negative human impacts
- Addresses simple and complex technology systems
- Can be applied by personnel involved in procurement (those conducting the exploratory studies were drawn from the same teams) but some questions may require human factors expertise to answer
- Beneficial for subject-matter expert to verify input data
- Analysis can be conducted relatively quickly and cheaply
  - non-specific usage: ~16 man weeks (range of use cases)
  - specific usage, e.g. in a UOR: ~ 4–5 man weeks (fewer but more focused use cases)



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Validation approach

- Several types of validity considered — each plays role in determining the fitness for purpose of a model or approach
  - *Construct validity* attained if model built using accepted theoretical constructs about how the object in question functions
  - *Content validity* attained if range of applicability of model (range of independent variables and component models) meets the requirement criteria of its intended use
  - *Predictive validity* attained if model capable of reproducing real-world observations to the required degree of fidelity for the proposed application of the model

- Two questions were considered:
  - Is the overall five-stage process fit for purpose (i.e. is the framework valid?)
  - What issues should be considered that contribute to the validity of an individual study (i.e. is a particular study valid in terms of construct, content and prediction)?

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Validation

- Framework
  - Content validity is provided by consideration of Defence Lines of Development and HFI domains since these are drawn from established enterprise level models
  - At the framework level the constructs used in Steps 1–3 are a plausible high-level description of the technology and its interaction with the human
  - All five steps are necessary and sufficient to provide a useful model of the impact process

- Individual study
  - more detailed analysis of both content and construct validity has to be applied to each of the steps in turn
  - recommended series of checks provided to assess whether all steps meet basic requirements

- For majority of studies it is not possible to demand predictive validity, as outturns will be in the future

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ombinations of technologies

hodology designed to assess human impacts of either a
gle technology or specified combination of technologies

ractice a number of potentially useful innovations will be
ieved by applying a combination of technologies

useful to ask:

'Under what conditions is it possible to bring together the analyses of positive and negative human impacts for the technologies in isolation to provide an assessment of their impact in combination?'

ny complex system, possible to assess impact of
cific component on overall system performance by
sidering effect of the component in isolation <u>if and only if</u>
component has no important interactions with any other
nponents in the system

s is a stringent condition that is unlikely to be met in all
umstances, and a preliminary study was undertaken to
ress this question

eliminary assessment of potential interactions

estion can be rephrased as whether a set of causal chains can simply be joined ether to provide a set of inputs and impacts that can be summed

eliminary analysis suggested that the following basic criteria may be employed

ausal chains do not have any ‘overlap’ or interaction, they can be joined and summed

tical interactions likely to exist anywhere in set of causal chains when technologies are:

- for use by the same person
- situated in the same work space
- involved in the execution of the same function

ese apply for all aspects of the employment of the system including operational use, intenance, logistics, pre-deployment activity

ositive and negative impacts from combining technologies

eractions between elements are the key to critical emergent properties in any complex tem

e focus of the analysis should be on these elements

portant to note that interactions can be both benign (under-additive and beneficial) or lign (over-additive and a negative impact)

he examples that follow the main interactions that are highlighted are those that are lign

some cases the impact will be positive and in the opposite direction

e main consideration is that the extra (possibly unexpected) emergent effects that arise m combining technologies will be sourced from the key interactions

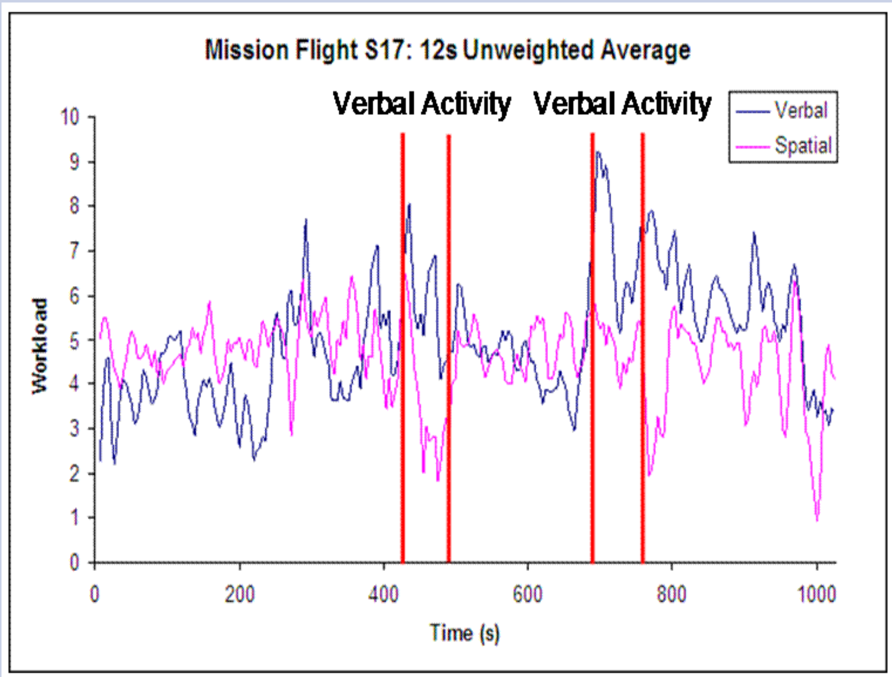
eractions involving the same person

sks undertaken by the individual are
ected adversely — workload increases,
grading performance on both tasks

n–Machine Interfaces (MMIs) for the
ltiple technologies may interact in an
verse way by demanding inefficient
sion of attention

ingle interface may provide access to
ltiple technologies, reducing the
ential impact

echnologies are to be carried by an
vidual, such as a dismounted soldier,
ues such as the impact of the combined
ght of the technologies become
portant



echnologies situated in the same workspace

two or more technologies to be installed in the same
k space, examples of pathways through which
ractions may occur were identified:

- location of equipment in small work space (e.g. aircraft cockpits or armoured fighting vehicles) may create additional hazards for the crew by taking up space
- may be sufficient power to support each technology in isolation but insufficient to support the combination, and revised power consumption may have negative impact on environmental temperature
- may not be possible to place the MMI such that functions allocated to a single individual can still be performed by one person

ironment mediates the interaction and its effect on the
w

echnologies involved in the execution of the same function

ction normally performed by team of
rators

rk conducted by a team comprises two
ments: performance of individual tasks
k work) and interactions between
mbers of the team (team work)

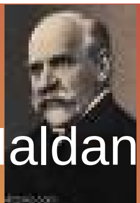
lysis of task work is covered by the
nge in function performed by an
vidual

mbination of technologies may affect the
y in which the team members interact —
ks may be moved from one team
mber to another and this may affect
m interaction (team work)

mode of interaction may also be
dified (e.g. from speech to electronic
mmunication)

verall summary

- Five-step methodology can be applied to analysis of range of technologies, e.g. from anti-fatigue glove to NEC
- Using Bayesian Belief Networks, possible to quantify military impact from relationship & quantification of positive and negative human impacts
- Can be applied by personnel involved in procurement (those conducting the exploratory studies were drawn from the same teams) but some questions may require human factors expertise
- Beneficial for an SME to verify input data
- Reduced method may be employed for rapid assessment of human factors concerns for an Urgent Operational Requirement
- Analysis can be conducted relatively quickly and cheaply (weeks)
- When applying the five-step method, attention should be paid to validation, through assessment of steps in the process to provide at least an assessment of construct and content validity

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