What is Technical Integrity and How to Measure It?

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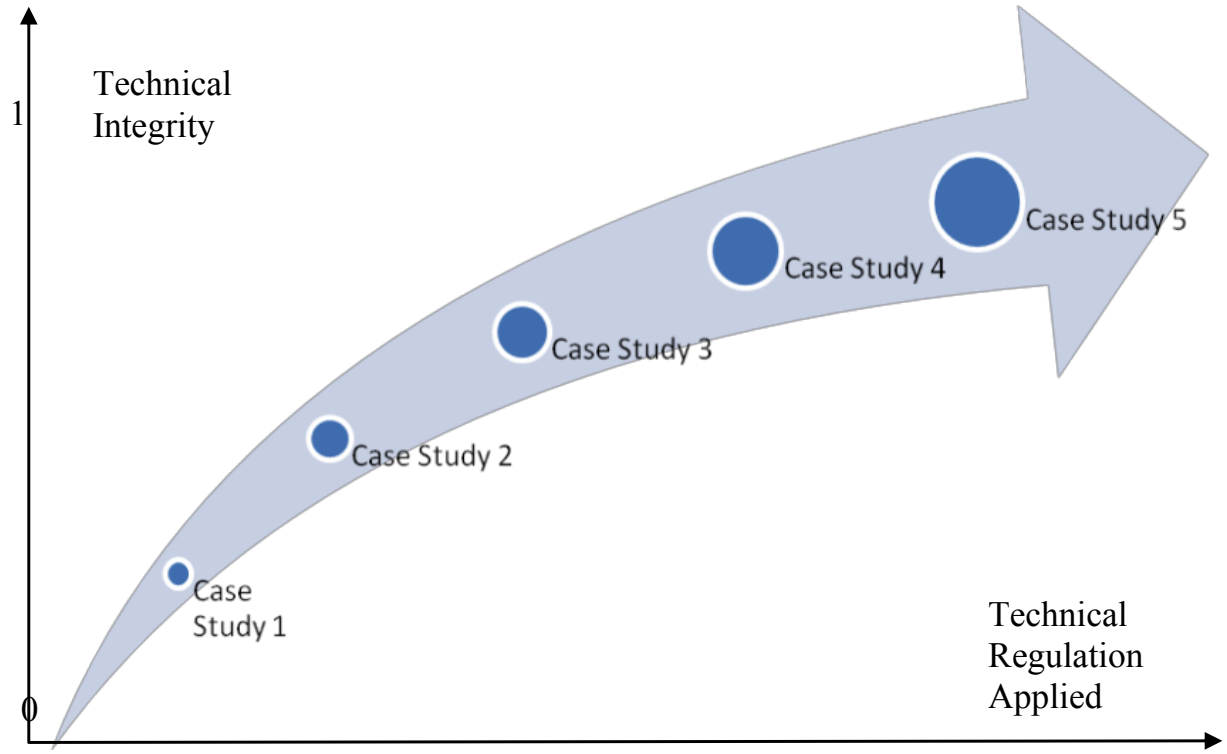
My Research Problem

- Hypothesis: Systems developed under Technical Regulation have higher Technical Integrity.



Motivated to measure *Technical Integrity*


INCOSE
International Symposium

Part 1

What is ***technical integrity***?

Many Definitions, Related Concepts, Usages and Stakeholders

Woodside-Shell: Integrity – achieved when risk of failure that endangers personnel, environment or asset value is tolerable and is reduced to ALARP.

ADF: Technical Integrity. Defence materiel is fit for service, and poses no hazard to personnel, public safety, or the environment.

System Effectiveness

Certification

ADF TAR: Technical Airworthiness

EO – Safety & Suitability for Service

NAVSEA: Mature, Safe and Reliable Warfare Systems

Systems Assurance

Product Quality

LR Ship Classification: Compliance with a set of RULES or other TECHNICAL STANDARDS that have been shown to be appropriate for the function of the ship/ platform.

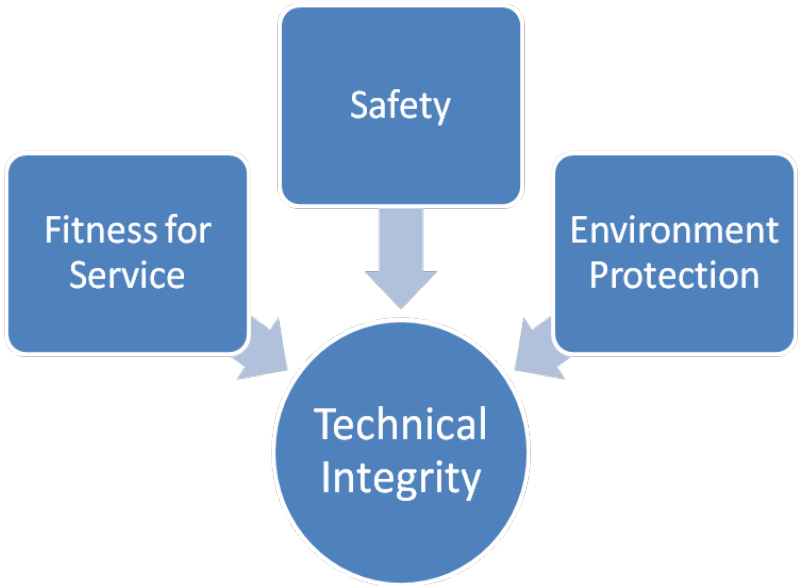
Fitness for Purpose

Technical Assurance

Mission Assurance

Technical Integrity in the Australian Defence Force (ADF)

- Fitness for service.
  - The systems ability to satisfy operational requirements.
- Safety:
  - Freedom from those conditions that can cause death, injury, or occupational illness
- Environment Protection:
  - Poses no hazard to the environment.



Other Views of Technical Integrity

- Process Plant Industry
  - "Integrity – achieved when risk of failure that endangers personnel, environment or asset value is tolerable and is reduced to ALARP"
  - "Technical integrity is concerned with the development of the design such that it is carried out by well trained personnel, who have been assessed to be competent, in accordance with recognized, sound practices and procedures and such that there is adequate provision by way of reviews and audits, to ensure the design intent is unimpaired in any way that could cause undue risk or harm to people or damage to the environment."
- Commercial Shipping – Lloyds Rules
  - Objective is "safe ships" via compliance with a set of rules
- NAVSEA certification policy to achieve "Mature, Safe and Reliable Warfare Systems"

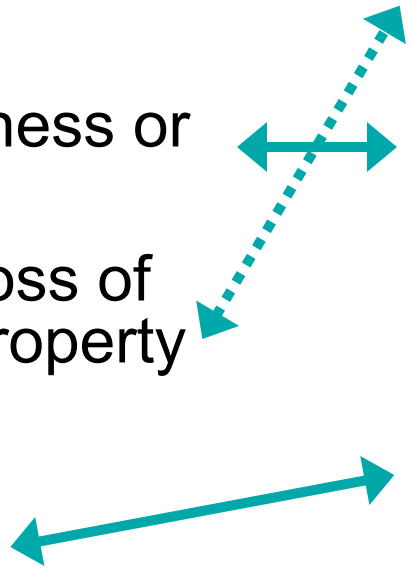
MIL-STD-882C System Safety vs ADF Technical Integrity

MIL-STD-882C Safety

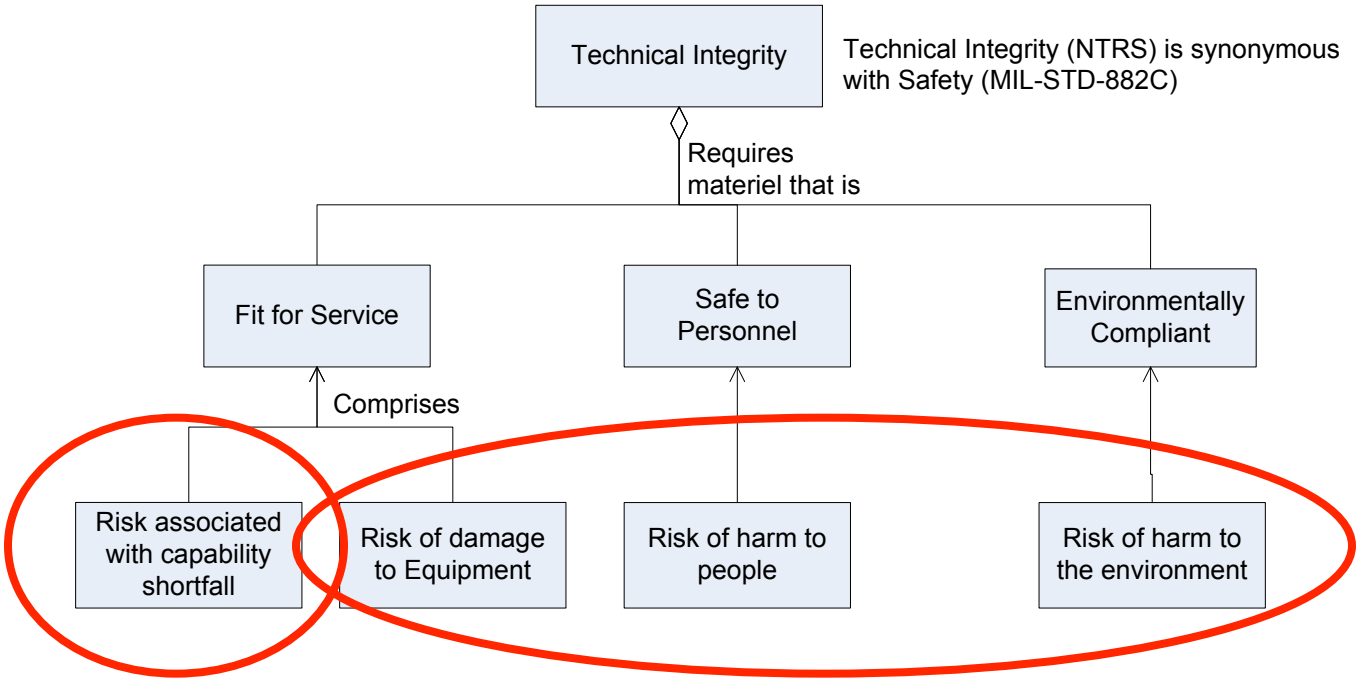
- Freedom from those conditions that can cause:
- Death, injury, occupational illness or
- Damage to or loss of equipment or property or
- Damage to the environment

ADF Technical Integrity

- Defence materiel is:
- fit for service, and
- only poses acceptable risk to personnel, public safety, or
- the environment.



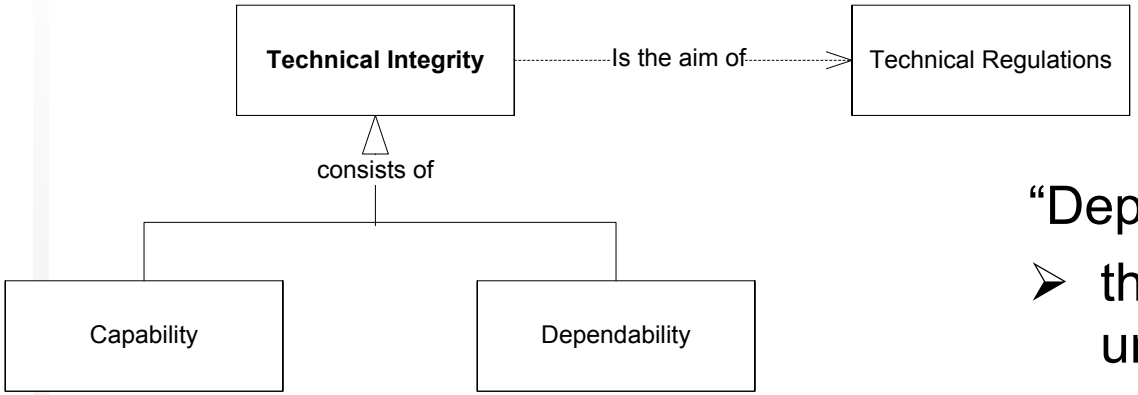
Common Elements of Technical Integrity, System Safety and Regulatory Objectives



Meet capability requirements

Minimise undesired consequences

Generalised Definition of Technical Integrity



"Capability"

- the system meets all specified requirements for performance, function and quality attributes
- In defined environment
- When used as intended

i.e., the "useful" emergent properties of a complex engineered system

"Dependability"

- the risk associated with unintended, undesired emergent behaviour of the designed system is acceptably low
- Includes concepts of robustness, reliability, safety, …

i.e., the "destructive" emergent properties of a complex engineered system

Part 2

How can ***technical integrity*** be measured?

Lord Kelvin is reported to have said

"I often say that when you can measure what you are speaking about, and express it in numbers you know something about it, but when you cannot measure it, when you cannot express it in numbers your knowledge is of a meagre and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely in your thoughts, advance to the stage of science whatever the matter may be".

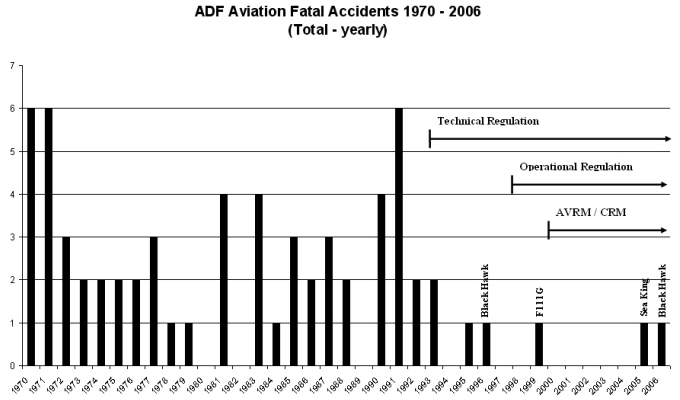
Objectives for a measure of Technical Integrity

- Must be objective
- Ideally a ratio scale
- At least an ordinal scale
- Applicable across classes of complex engineered systems
- Must be able to be evaluated by quantitative and/or qualitative data that may be practically obtained for complex engineered systems

Extant Support for a Measure

- Literature review:
  - Some views that
    - there is no single overall measure for the quality or integrity of a complex engineered system
    - Many factors not measurable
  - value hierarchy for concepts like “System Effectiveness” for a complex system, as a combination of capability, reliability and availability
  - Concepts of quality or integrity being a value only determined by system stakeholders
  - Views that quality attributes should be quantified

- Proxies for Technical Integrity
  - Accident/incident rates of a system in the operations phase of its lifecycle
  - Compliance with requirements
  - Dependability assessments

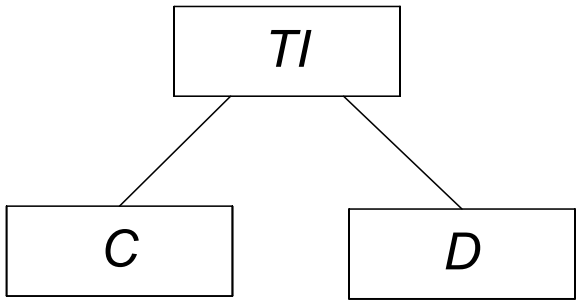


It’s feasible (and desirable) to measure *Technical Integrity*

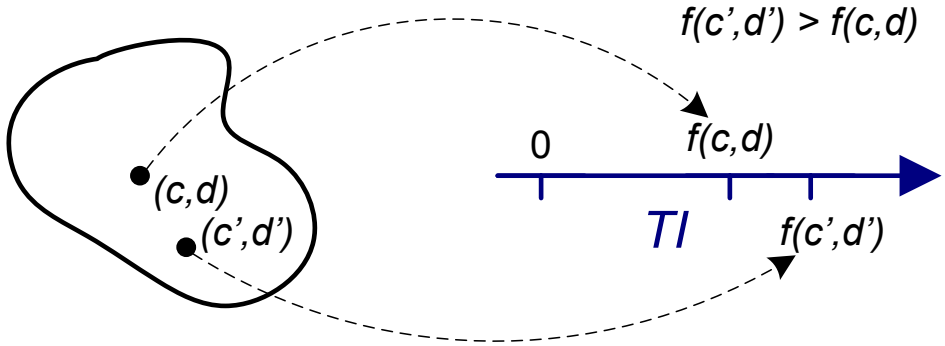
Selecting a Form of Measurement

- Direct measurement – *rejected*
- Indirect measurement
  - Derived – *rejected*
    - No known law to combine direct measurable properties
  - Associative - *rejected*
    - no empirically known relationships to combine direct measurable properties
  - Multi-dimensional measurement - *rejected*
    - Cannot produce desired ordinal, interval or ratio scales
  - Conjoint measurement – *accepted*
    - combine a range of *decomposed* factors and define mathematical combinations that provide an empirical ordering or values of Technical Integrity

Conjoint Form for TI Measurement



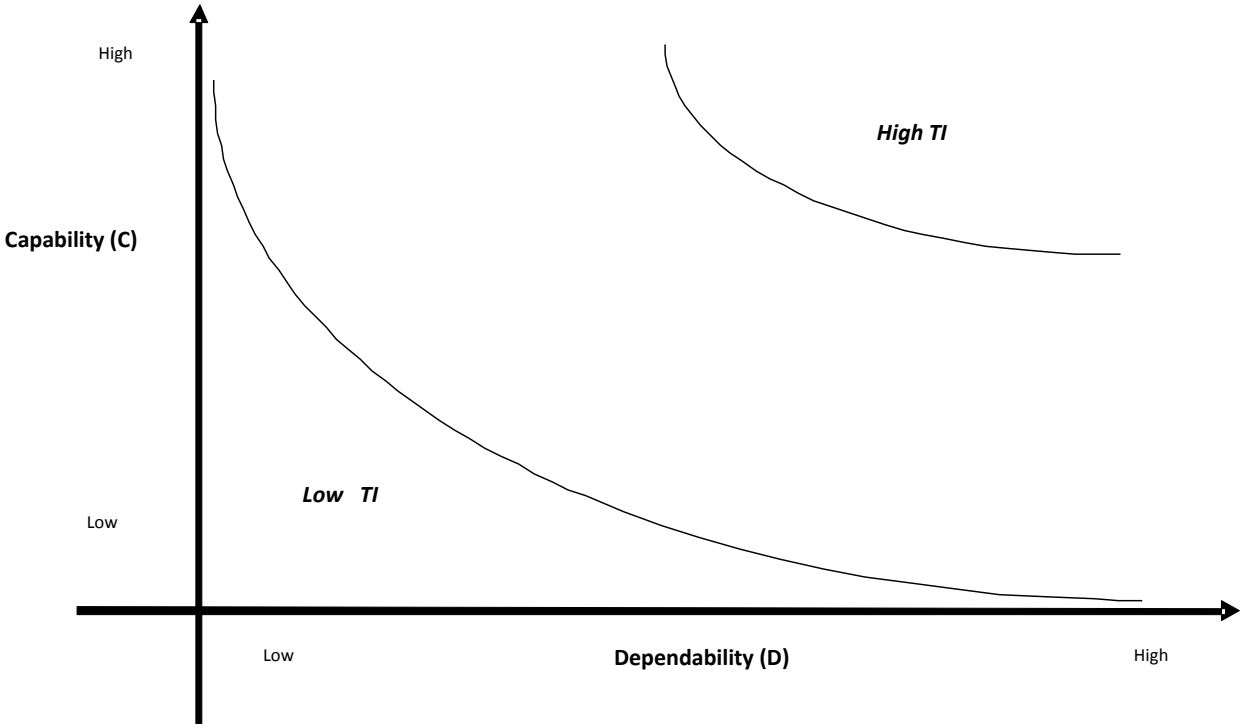
(i)



(ii)

$$TI = f(C, D)$$

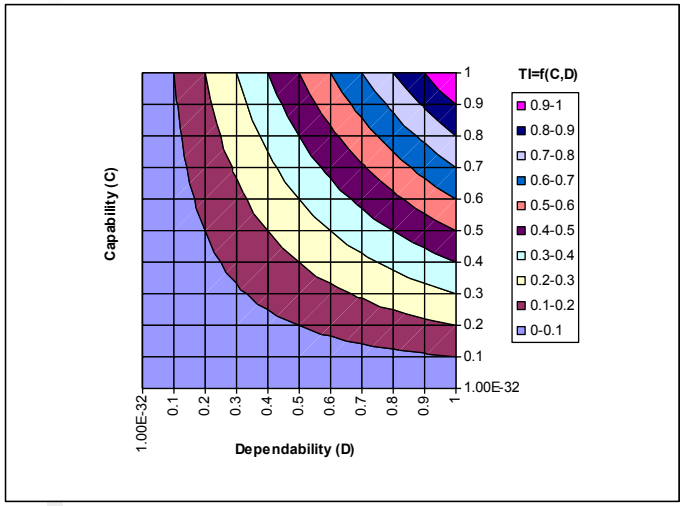
Expected Characteristics of the Conjoint Measure

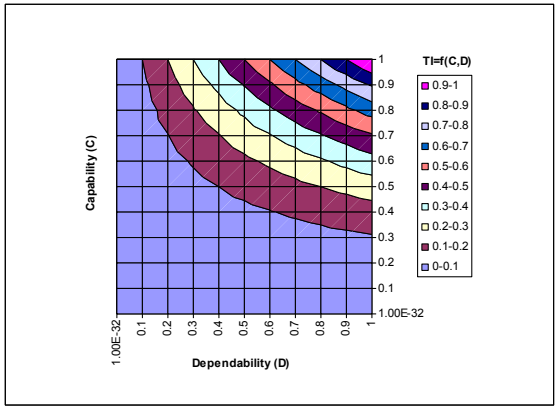


$$TI = f(C, D)$$

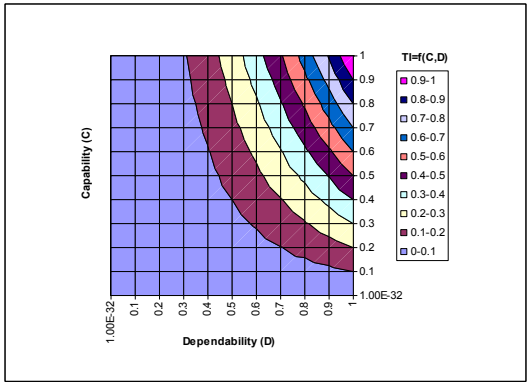
Multiplicative Conjoint

$$TI = C^{\alpha}.D^{\beta}$$





Capability Biased



Dependability Biased

Capability Measurement

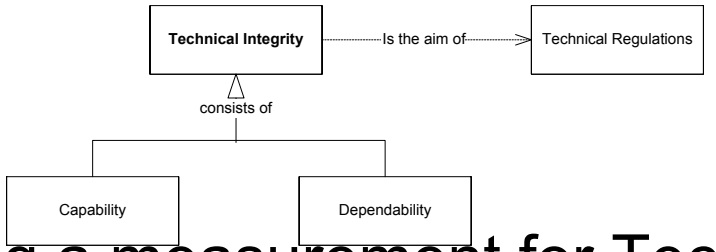
- Requirement satisfaction related measures.
- Approaches
  - Measure directly – e.g. percentage of requirements achieved by a completed system
    - Practicality – most system development projects keep detailed requirements metrics, but may not be readily disclosed to researchers
  - Measure indirectly – e.g. subjective evaluations by expert stakeholders f capability mapped to a ordinal scale

Dependability Measurement

- More difficult
- Is it Feasible?
  - Plausible at least on an ordinal scale (can say System A is more dependable than System B)
- Potential approaches
  - Identified risks in a system are typically characterised at least in qualitative terms – e.g. as a consequence-likelihood pair
    - Convert these to a value and sum to get a measure of overall identified residual risks
  - Unidentified risks in a system
    - Need some measure – e.g. use techniques like those used for residual fault estimation in complex software
  - Actual incidents/accidents occurring/recorded – even minor incident occurrence rates can give an indication of *dependability*
  - Subjective approach – e.g. as done for the System Usability Scale – expert evaluations across a range of important contributing factors

CONCLUSION

- Generalised definition of technical integrity derived as a basis for ongoing research
  - Intended, desirable emergent properties – *capability*
  - Unintended, undesired emergent properties - *dependability*



- Constructing a measurement for Technical Integrity is feasible
  - Conjoint approach selected
  - Measurement of conjoint factors;
    - Practical means available for *capability*
    - 4 potential means for measuring *dependability identified for ongoing research*