2023
Annual INCOSE
international workshop
HYBRID EVENT
Torrance, CA, USA
January 28 - 31, 2023

EXPERIENCES WITH QUANTITATIVE ASPECTS OF REQUIREMENTS

by Carlo Leardi, CSEP, AISE Incose Italian Chapter

Associazione Italiana di Systems Engineering
AISE
INCOSE Chapter Italia

Carlo Leardi, CSEP

Graduated in **electronic engineering** in Genova Italy.

Started with *quality assurance* responsibility evolving in the last years to *full verification and validation* commitment within complex systems development deployment projects in the following areas: **automotive, freight railways** and for more than 25 years **packaging industry.**

As a passion before and today as a full job, he is dealing with **Quantitative Systems Engineering** on a day-to-day *application and coaching* of a full range of **statistical and simulation methodologies** *supporting the decisional process.*

Several articles published in Engineering and Systems Engineering journals. CSEP certified, *founder* and past President of the ***INCOSE Italian Chapter*** and *founder of **AISE***, the Italian association of Systems Engineering.

Teacher at Systems Engineering Masters in Tor Vergata, Rome, and ForteMare in La Spezia.

Serving the Incose Italian Chapter as director of events and coordinator of the Verification, Validation and Operation working group.

Agenda:

- What: Quantitative aspects of requirements (explicit, implicit)
- Why: value and value loss
- When and where
- How
- How much
- Wrap-up
- References

What: quantitative aspects of requirements

MVP in a agile?

Any operator?
Ability?

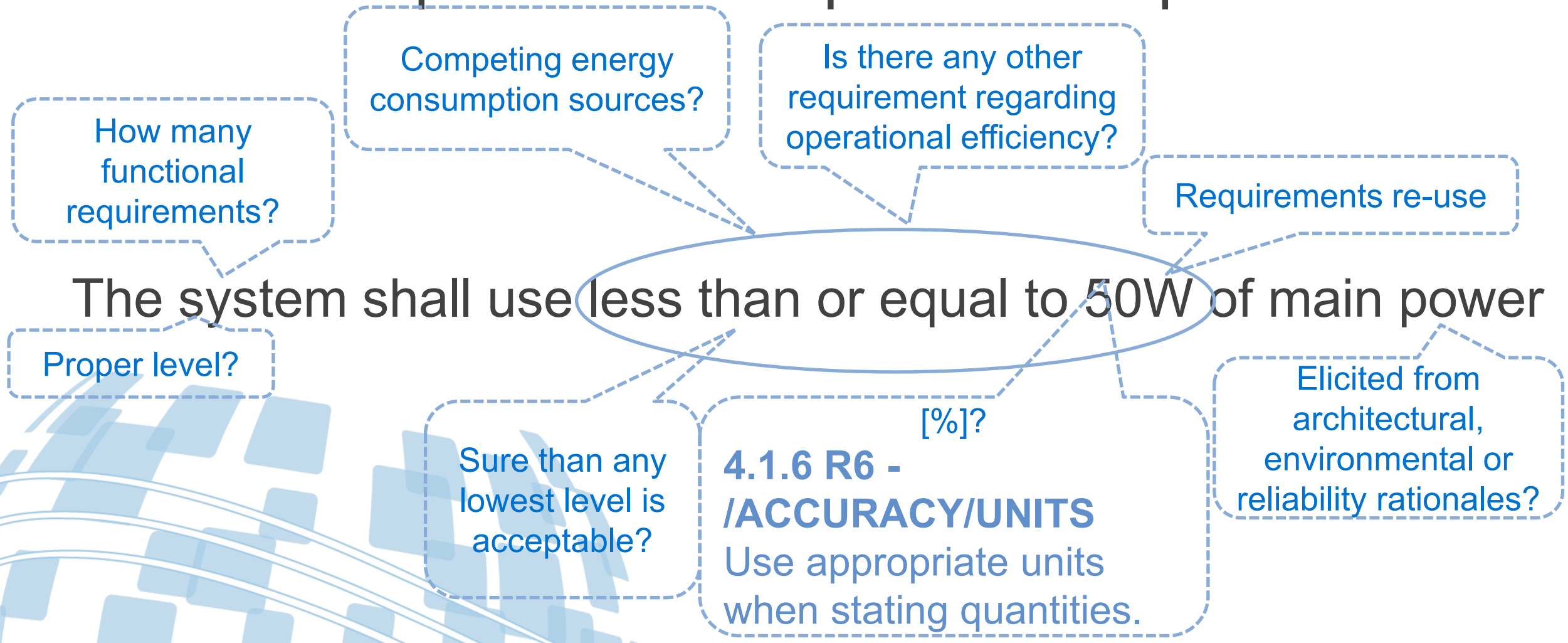
The system shall allow the operator to brew six cups of coffee with a volume of 236 ml for each cup without refilling the system with coffee beans, water and without emptying the puck waste.

Coffee beans, water and puck waste capacity?

Short term (daily?) maintenance time/skills?

**INCOSE-TP-2021-004-01 | VERS/REV:1.0 |May 2022*

What: quantitative aspects of requirements



*INCOSE-TP-2021-004-01 | VERS/REV:1.0 |May 2022

What: quantitative aspects of requirements

4.10 Quantifiers
4.10.1 R32 - /QUANTIFIERS/UNIVERSALS
Use “each” instead of “all”, “any”, or “both” when universal quantification is intended.
The use of “all”, “both”, or “any” is confusing because it is hard to distinguish whether the action happens to the whole set or to each element of the set. “All” can also be hard to verify unless “all” can be clearly defined as a closed set. In many cases, the word “all” is unnecessary and can be removed, resulting in a less ambiguous need or requirement statement.

List, type, risk, limitations?

The Weapon_Subsystem shall store the Location of all Ordnance

Database security must meet HIPAA requirements

Current version specificities?

The <product> shall be FDA approved

Which quantitative aspects must be taken into account?

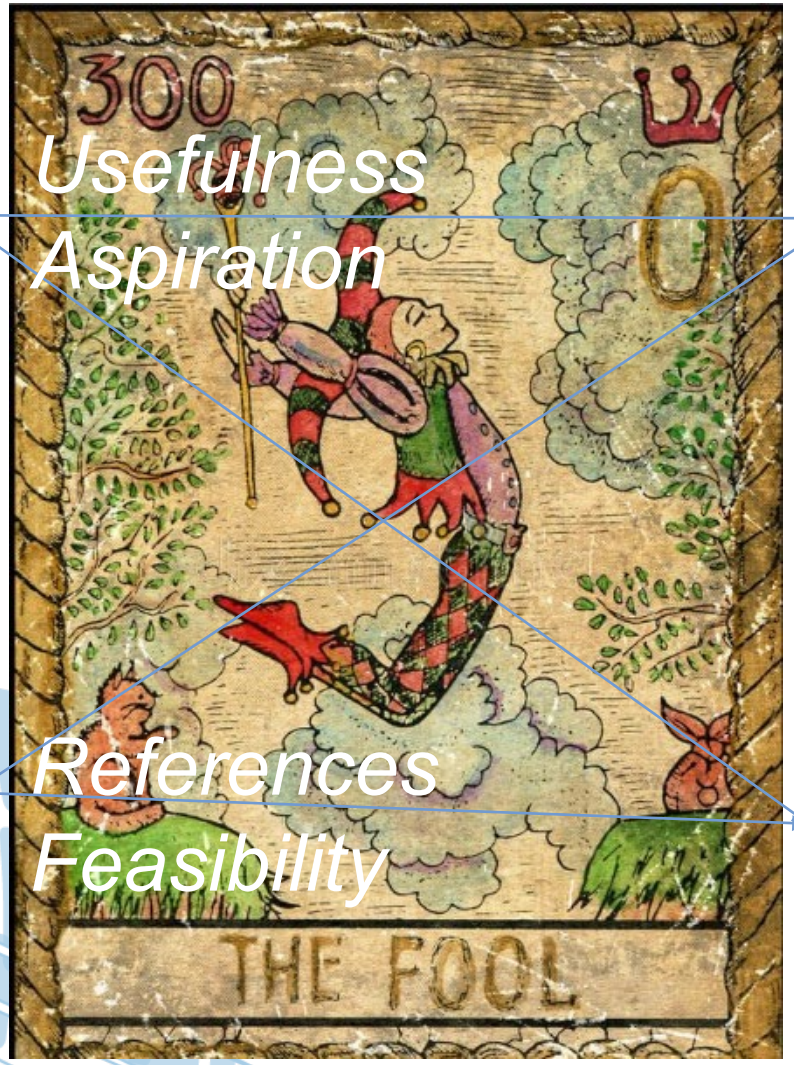
**INCOSE-TP-2010-006-04| VERS/REV: 3.1 | May 2022*

Why: value/value loss

Value to costumer, users, consumers and humanity

Validation

Competition, regulations, standards



Internal quality level

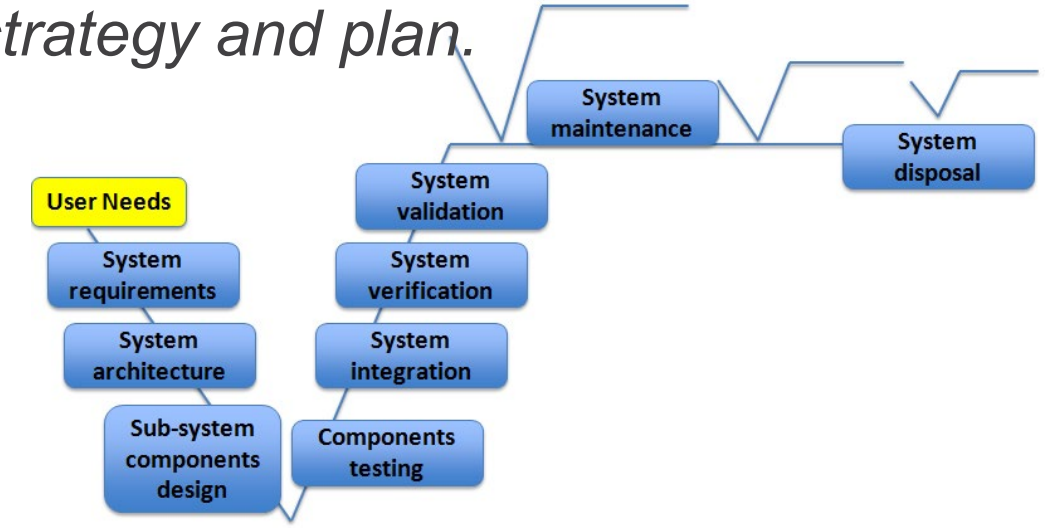
Verification

Technology, verification and validation opportunities

User needs

Collect, identify and refine the **user needs**, understand project **challenges**, identify **usage scenario** vs. baseline

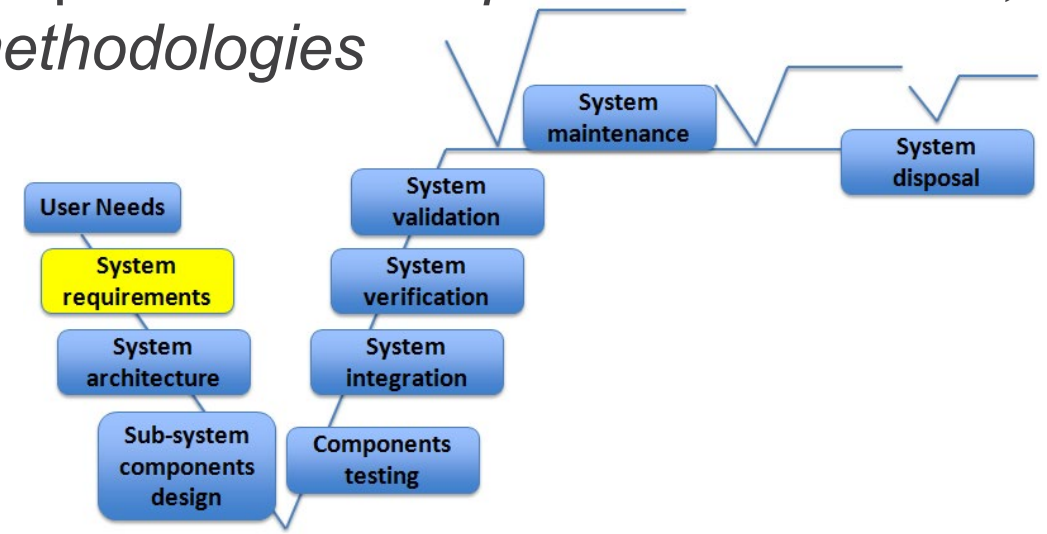
- Business or Mission Analysis, Market trends analysis and customers appraisals: *qualitative/quantitative analysis, Kano models*
- *KPI & MOE target definition: e.g. Op. Cost, Ppk, OEE*
- User needs quality assessment: *testable targets*
- Usage scenario: *Big data, Multivariate Data Analysis*
- *Set-up Validation strategy and plan.*



System requirements

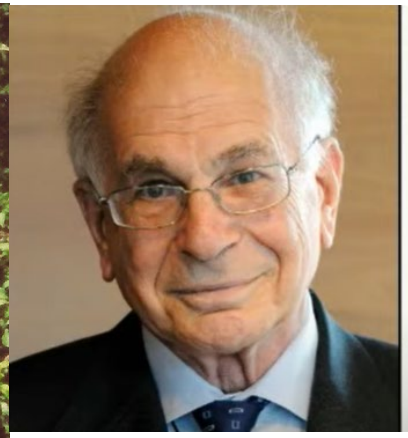
Define and qualitatively assess the System Requirements:

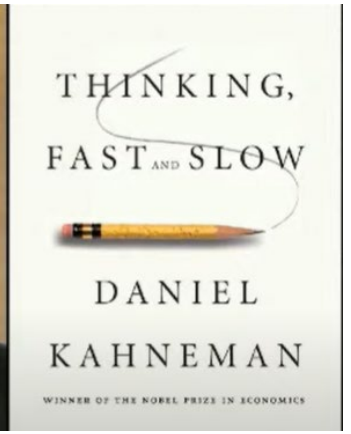
- Targets definition: *Inferential statistics, TPMs: TBF, TTR, binomial, poisson, and normal*
- Evaluate the technical opportunities: *ANoVA, inference*
- Verification strategy and plan: *Combine practical statistical, technical and business methodologies*

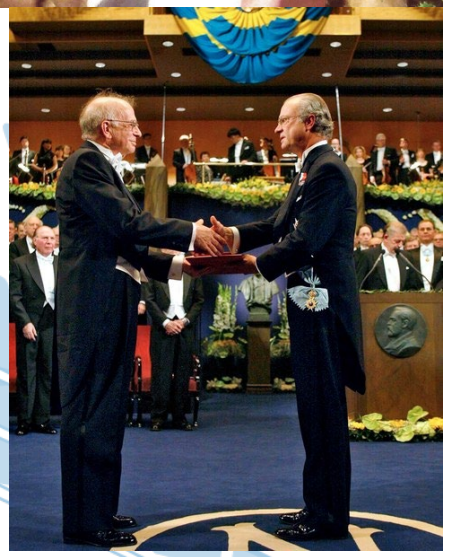


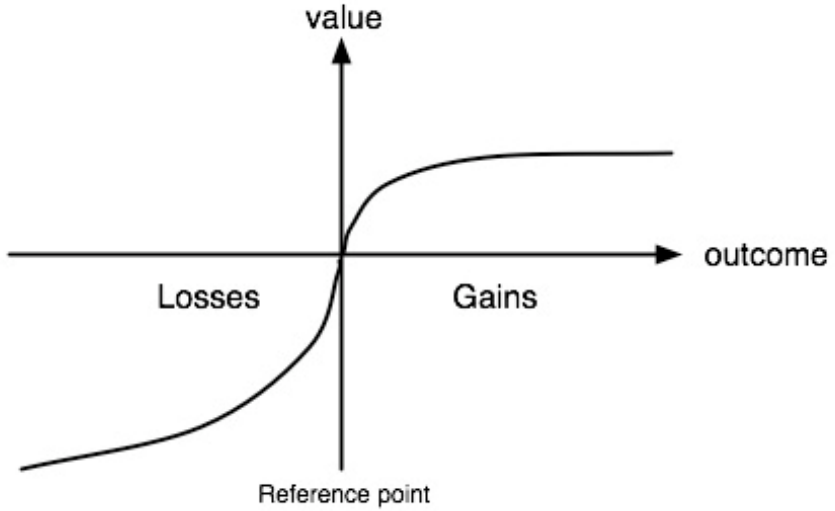
A descriptive model: Kahneman and Tversky

The prospect theory: Kahneman, Tversky, 1974: cognitive biases.
Finalized in 1992, Nobel prize in 2002

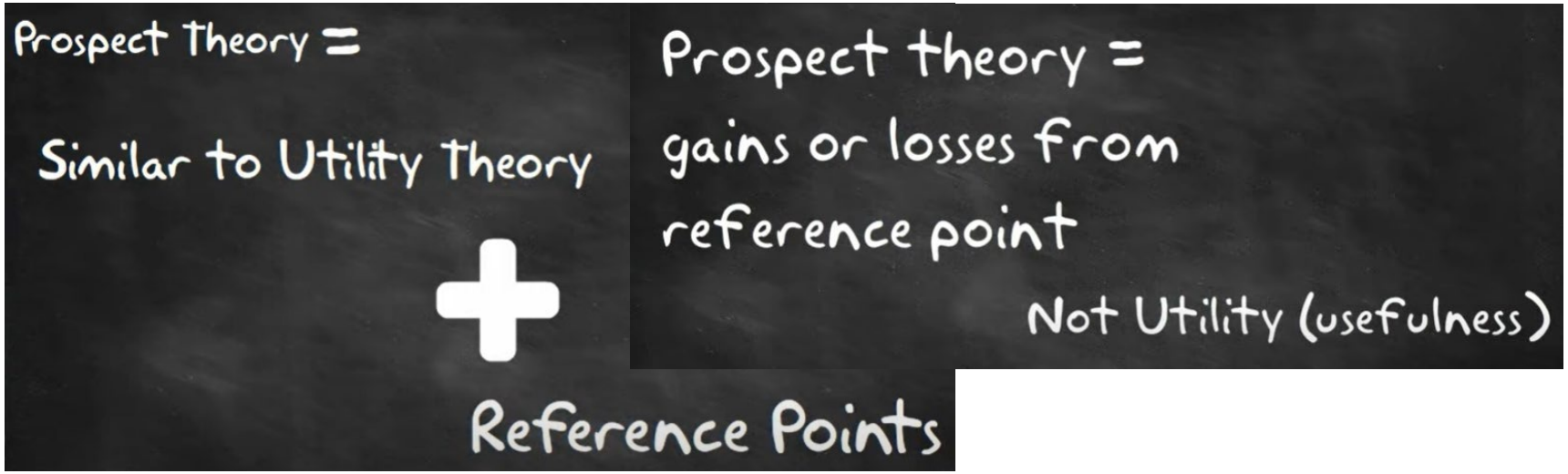


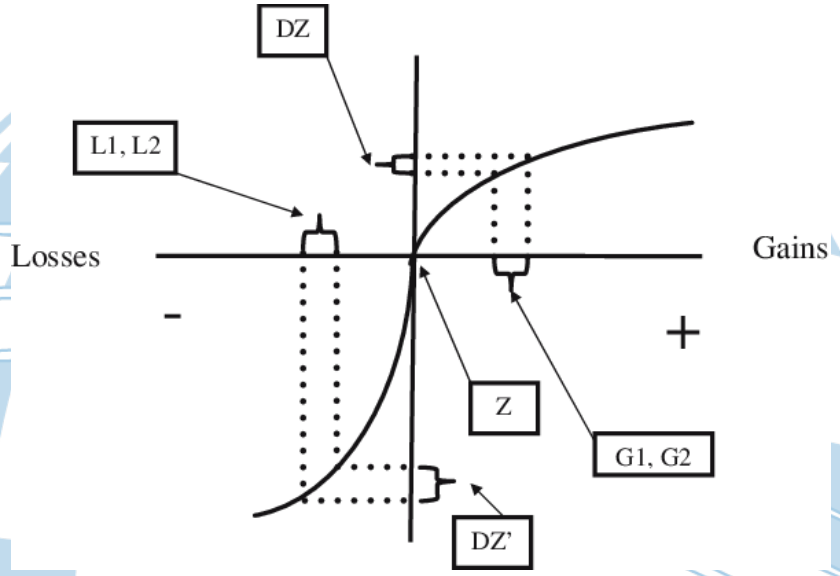






How much: prospect theory, Kahneman and Tversky





What you currently have? (status quo bias)
What you get if you do nothing? (omission bias/inertia)
What you expect to get? (personal equilibrium)
What customers/users/consumers have? (other regarding preferences)

When/where

Need elicitation:
Home coffee pot for family consume in the US market

"The system shall allow the operator to brew six cups of coffee with a volume of 236 ml for each cup without refilling the system with coffee beans, water and without emptying the puck waste."

Heating system, coffee beans, water tank, puck waste dimensioning. Analysis

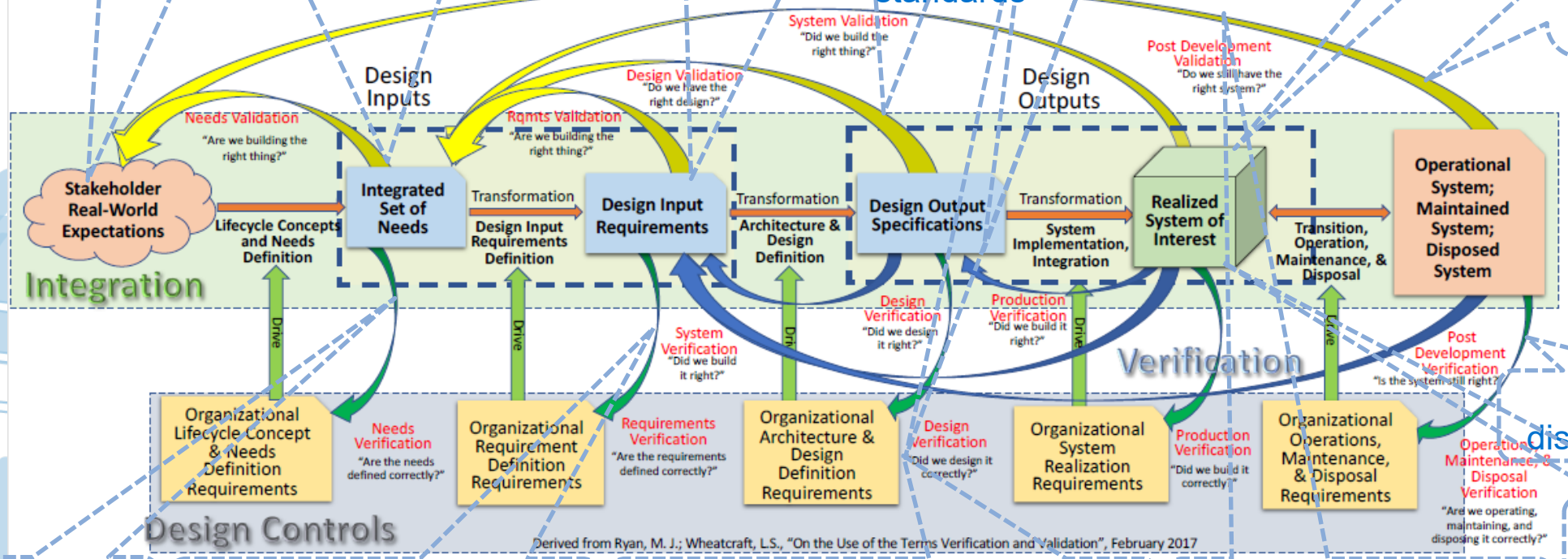
Demonstration Robustness confirmation. (wearing, usage conditions)

Usage instructions feedbacks. (wearing, limit usage conditions)

One day without refilling and cleaning

Compliance to standards

Verification and Validation in Context



Consumables disposal procedures?

Industry 4.0

Conflicting needs?

Overlapping requirements?

Systems requirements still satisfied?

robustness verification?

How:

Rationales for six cups?
"Not too often"?
Couldn't it be too much?
E.g. water quality degradation?

Verifiable by:
Analysis
Test? ➔ repetitions required?
Robust Design
Demonstration (AI, VR) ➔ Validation

The system shall allow the operator to brew six cups of coffee with a volume of 236 ml for each cup without refilling the system with coffee beans, water and without emptying the puck waste.

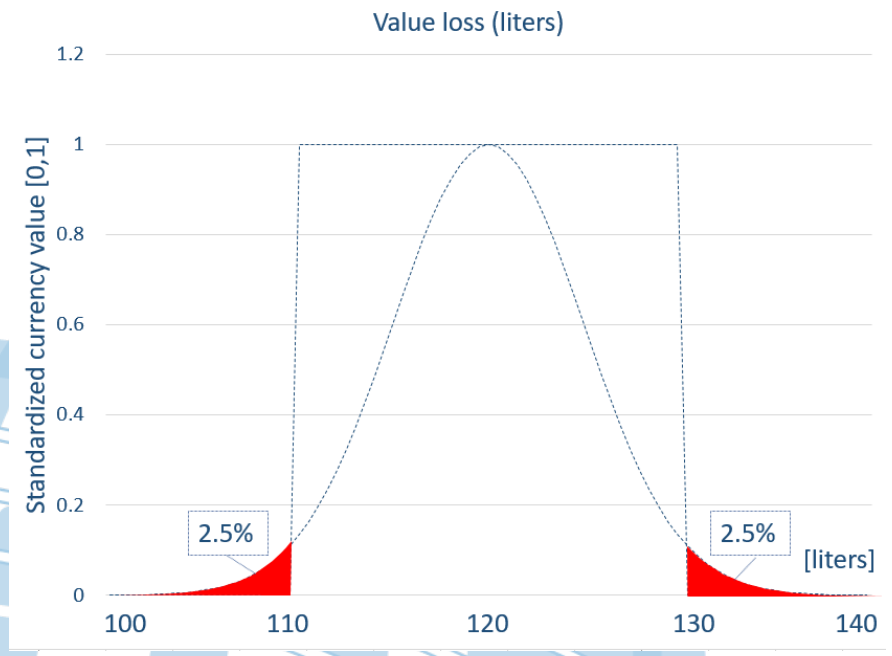
Architectural constraints: dimensions, max power, safety, maintenance operations, …

Alias 0.99751 US customary cups. ≅ one-half US pint

*INCOSE-TP-2021-004-01 | VERS/REV:1.0 |May 2022

How much: quantitative is quantitative!

The Pumping_Station shall maintain a flow of water at 120 ±10 liters per second for at least 30 minutes.



Not one second less? One-sided, two-sided

Section 4: Rules for Need and requirement statements and Sets of Needs and Requirements

4.1.7 R7 - /ACCURACY/AVOIDVAGUETERMS

Avoid words that provide vague quantification, such as “some”, “any”, “allowable”, …

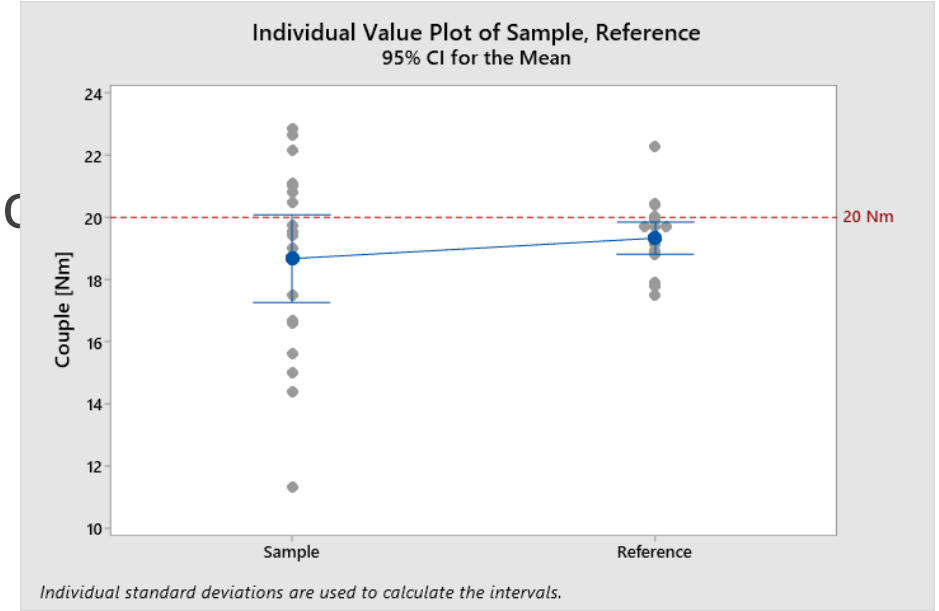
4.11.1 R33 - /TOLERANCE/VALUERANGE

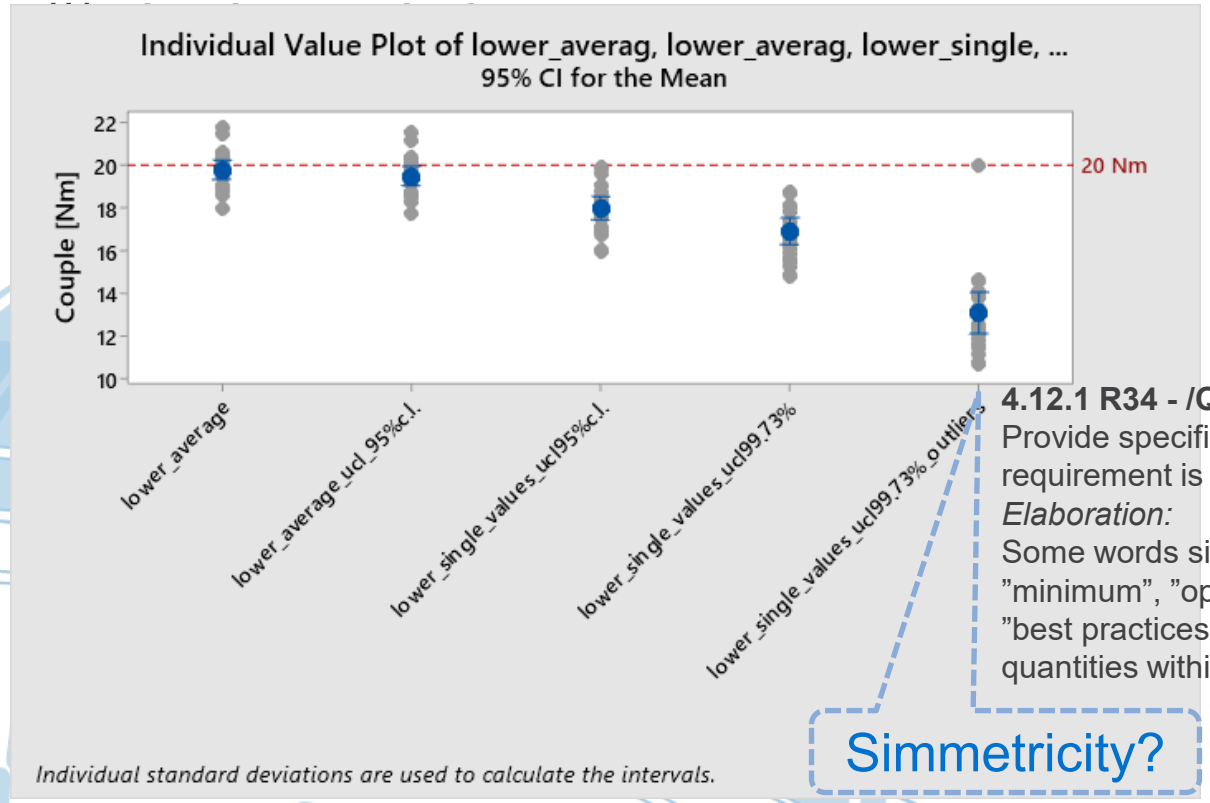
Define quantities with a range of values appropriate to the entity to which the apply and to which the entity will be verified or validated against.

**INCOSE-TP-2010-006-04 | VERS/REV:3.1 |May 2022*

How much: quantitative not qualitative!

The couple shall be not **worse* than** 20 Nm
The couple shall be **better* than** 20 Nm
The couple shall be **comparable with** referenc





Simmetricity?

4.12.1 R34 - /QUANTIFICATION/MEASURABLE
Provide specific measurable performance targets appropriate to the entity to which the need or requirement is stated and against which the entity will be verified to meet.
Elaboration:
Some words signal unmeasured quantification, such as “prompt”, ”fast”, ”routine”, ”maximum”, ”minimum”, ”optimum”, ”nominal”, ”easy to use”, ”close quickly”, ”high speed”, ”medium-sized”, ”best practices”, and ”user-friendly.” These are ambiguous and need to be replaced by specific quantities within feasible ranges that can be measured.

How much: The reference issue

The <semi-finished material> position in front of the <reference>
shall **not** be farer than 2 mm
shall be within ±2 mm
shall be ±2 mm at 95% c.l.
shall be ±2 mm at 99.73% c.l.
shall have an accuracy of ±1 mm and a precision of ±0.67mm at 95% c.l.

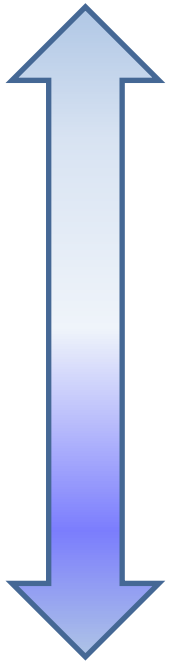
4.3.5 R16 - /NONAMBIGUITY/AVOIDNOT
Avoid the use of “not.”
The presence of “not” in a need or requirement statement implies “not ever”, which is impossible
to verify in a finite time.
4.11.1 R33 - /TOLERANCE/VALUERANGE
Define quantities with a range of values appropriate to the entity to which the apply and to which

How much: reliability requirements

The <consumable> shall have:

- ***Expected life** = 10.000 cycles*
- *Mean Life **(MTTF)** = 10.000 cycles*
- ***MTBF** = 10,000 cycles*
- *Failure rate = **0.0001 failures** per cycle*
- ***B10 life** = 10,000 cycle*
- *90% Reliability at 10,000 cycle*
- ***95%** Reliability at 10,000 cycle*
- *90% Reliability at 10,000 cycle **with 90% confidence***
- ***99.9%** Reliability at 10,000 cycle with 90% confidence*
- *90% Reliability at 10,000 cycle with **30%** confidence*
- *90% Reliability at 10,000 cycle with **95%** confidence*
- *90% Reliability for 10,000 cycle with 90% confidence*
- *90% Reliability for 10,000 cycle with 90% confidence for a **98th percentile customer***

Clearness



Completeness

Just as when setting a reliability goal the apportioned goal for purchased elements require all four elements:

- Function – often detailed in a requirements document
- Environment – use conditions and profile details
- Duration – length of time or number of cycles
- Probability – likelihood of successfully functioning over the duration

https://www.weibull.com/hotwire/issue80/relbasics80.htm

Wrap up

- Descriptive, qualitative and quantitative, sides of the same coin?
- Quantitative aspects in needs and requirements always relevant, special way before and after development.
- Relevance of needs and requirements validation.

2023

Annual INCOSE international workshop

HYBRID EVENT

Torrance, CA, USA

January 28 - 31, 2023

www.incose.org/IW2023