

# Tailoring and Combining the CMMI-ACQ and Quality Models to Improve the Military's Requirements Process

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# Improving the Military's Requirements Process

## The requirements process in general

- A **top-5** issue in all systems/software engineering studies.
- **Requirements stakeholders' different value propositions** a primary reason

=>The military's approach to requirements development in policy & practice

- **Sponsorship** for requirements **shifts** throughout the JCIDS process
- **Users** are joint developers of requirements and can play the role of sponsor
- JCIDS KPPs – partial fit with other **quality models** & **usability** marginalized
- Yet **usability** can be at issue in requirements development & testing

## Content analysis of CMMI-ACQ re JCIDS, quality models & problem reports

- Content Analysis **Techniques**
- **Findings**: re Customers & Users, Organization, Usability & Other Quality Attributes
- **Building a Concept Space for Defining Quality Attributes in Practical Contexts**

Using **Meta-Modeling** to Tailor, Combine, Apply & Improve Policy & Models



# The Military's Approach to Requirements: JCIDS

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*JCIDS is the Joint Capabilities Integrated Development System*

*JCIDS a Joint Chiefs* approach to requirements development to

- *“stop paying for the same things twice”* or even multiple times:
- *Negotiate & reconcile differences in value proposition* among:
  - Combatant Commanders
  - Science and Technology Representatives
  - Combat Developers
  - Material Developers
  - Testers and Evaluators
- focus on *Key Performance Parameters* (KPPs)
  - Overlap with other *quality attribute* models
  - KPPs supported by Key System Attributes (KSAs)
  - Other Attributes of importance in particular contexts



# Quality Attribute Coverage Discussed in JCIDS

Examples of Quality Attributes in JCIDS are:

- **Survivability** KPPs like **speed, maneuverability, detectability, and countermeasures** reducing likelihood of being engaged by hostile fire
- **Operational Suitability including Sustainment** KPPs such as Materiel **Availability\*** and a supporting KSAs, Materiel **Reliability, Maintainability, supportability, safety**
- **Net-Ready KPPs** like **interoperability** that are to be used in Information Support Plans to identify support required from outside a program
- **KPPs covering characteristics of the future force:** being knowledge empowered, networked, expeditionary, **Adaptable/tailorable (Adaptability, Changeability, Modifiability)**, enduring/persistent, **Accuracy**, lethality, and precise, fast, resilient/agile (**Efficiency/Performance**)
- **Information Assurance KPPs (Security)** that protect availability, integrity, authentication, confidentiality, and non-repudiation.

**Attributes outside or marginal to KPPs, KSAs & value determiners, e.g.,**

- **Usability**, or what JCIDS calls Human Systems Integration (HSI).

*\* Named in other quality models – ones not named are military specific*



# ISO/IEC 9126 – Software Product Quality

## Quality Characteristics

## Sub-characteristics

### • **Functionality**



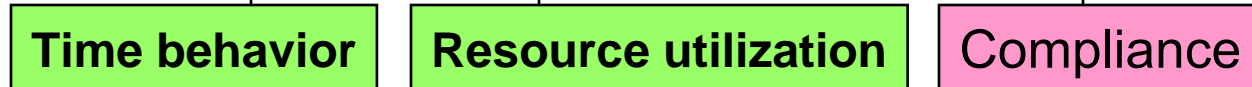
### • **Reliability**



### • **Usability**



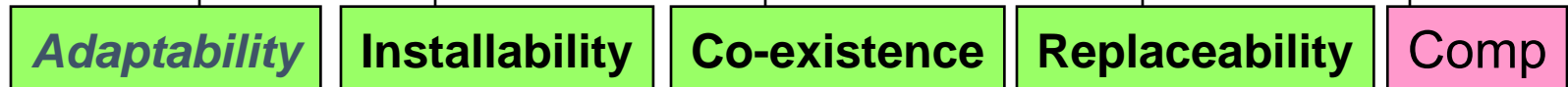
### • **Efficiency**



### • **Maintainability**



### • **Portability**



# Quality Attribute Scenarios: For SW Architecture\*

	Source of Stimulus	Stimulus	Artifact	Environment	Response	Response Measure
<b>Availability*</b> (Reliability)	External to System	Unanticipated Message	Process	Normal Operation	Inform Operator	No Downtime
<b>Modifiability</b> (Maintainability)	Developer	Change UI	Code	Design Time	Modification & No side effects	In three hours
<b>Performance</b> (Time behavior)	Users	Initiate Transactions	System	Normal operations	Transactions processed	Average latency of two seconds
<b>Security</b> (Security)	Correctly identified individual	Tries to modify information	Data within system	Normal operation	System maintains audit trail	Correct data restored within a day
<b>Testability</b> (Testability)	Unit Tester	Performs Unit Test	System component	Component completion	Component behavior observed	85% path coverage achieved within 3 hours
<b>Usability</b> (Usability)	Users	Minimize impact of errors	System	Runtime	Cancel current operation	Cancellation takes less than one second

\* SEI SW architecture quality attribute – ISO/IEC 9126-1 terminology in parenthesis – sometimes as sub-characteristics. ISO covers additional sub-characteristics that SEI SW architecture does not.



# Usability in Requirements Development & Testing

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Analysis of requirements documents & problem reports and interviewing at several military sites identified problems downstream that could be mitigated by documented considerations upstream.

One of the patterns identified suggests *usability* is not being considered, articulated & quantified during requirements development **because**

- functional criteria are better understood
- usefulness of a system is perceived as so important that users will learn how to use it in spite of usability issues
- operability issues can be fixed as they arise or deferred according to urgency.

**Other reasons:** a requirements developer prior to testing would have to

- know all the situations where a usability scenario applies
- formulate scenarios, at levels below the sub-characteristics of ISO 9126, re
  - o potential data entry error and feedback
  - o display of misleading alerts and warnings
  - o understandability of display & operability of a PDA reusing software from a desktop computer
  - o a maintainability feature (e.g., a stack dump) causing a disruption that could interfere with usability.



# Focusing Content Analysis 1: *Issues Combining JCIDS Policy, Quality Models and Practice*

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Combatants, their representatives, acquirers, maintainers and testers can be ***full-fledged participants in requirements development***.

- All must know how to participate in design reasoning
- All must collaborate in the evaluation and test of Systems of Systems.

Requirements processes can ***shift responsibility*** re specification of

- user/customer requirements (operational capabilities)
- contractual requirements (acquisition's translation for developer understanding)
- system requirements (developer's/sustainer's translation of contractual requirements)
- system of systems requirements.

***Quality attributes can be specified early***, starting with ***usability***.





# Focusing Content Analysis 2: *Disconnects between Practice, Policy, Quality Models & the CMMI-ACQ*

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Analysis guided by disconnects between:

- On the one hand, issues with respect to JCIDS & current military practice
  - multiple organizations have to share processes
  - users and customers can be JCIDS sponsors
  - quality attributes in the form of KPPs are essential
- On the other hand, elements of CMMI-ACQ, i.e.:
  - Single stable acquisition organizations are responsible for both customer and contractual requirements
  - Customers and end users are the sources for requirements
    - acquirers take full responsibility for specifying requirements
  - Quality attributes are factors to consider when expressing requirements, but are not essential.



# What is Content Analysis?

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***Content Analysis:*** a well-understood methodology

- to study documented communication
- using systematic, replicable techniques
- compressing many words of text into a few categories via explicit rules of coding.\*
- that predicted bombing of London by the Germans by analyzing Goebbels' speeches

\* Authors consulted are Berelson, 1952; Krippendorff, 1980; and Weber, 1990



# Content Analysis Techniques\* 1

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## Automated text analysis

- Tools identify recurring concepts & themes
- Employs computational algorithms using Bayesian conditional probabilities
- Similar to factor analysis

## Semantic classification, inference & validation

- Initially by analysts using the text analysis tool who:
  - classify automatically generated themes semantically
  - infer Quality Attributes (or other conceptual content)
- Iterative corroboration & enhancement with domain experts
  - Fully engaged to identify their own most problematic areas.

\* A number of tools have been used, CAIR (developed at the SEI), Semio Text, TextSmart, Lexiquest Mine and Leximancer. This is not an exhaustive list and SEI does not rank them in any way.



# Content Analysis Techniques 2

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Progression from Text to Concept to Theme \*

- **Text blocks (usually several sentences) are where concepts co-occur**
- **Concepts** are **synonym lists** of strongly related co-occurring **terms**
- **Themes** are **collections** of co-occurring **concepts**
  - more strongly related to each other than to concepts in other themes
  - automatically named by the concept most strongly related to other concepts in the theme.

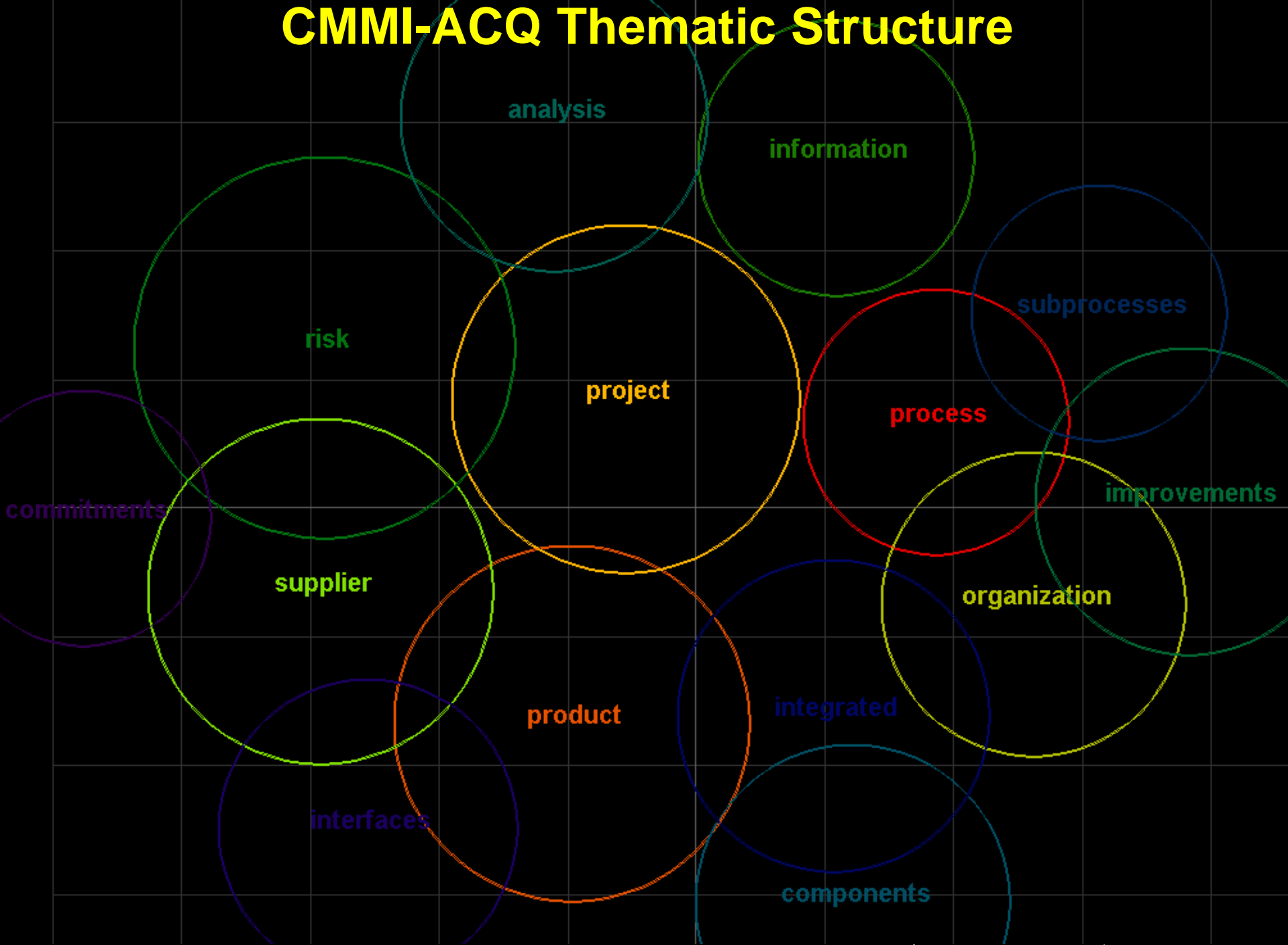
Themes containing concepts are represented spatially as Venn diagrams

- concepts labeling dots are in themes represented as circles
- dots can be linked by lines whose brightness represents frequency of co-occurrence
- dots can appear in the overlap of two (or more) circles
- circle size based on distribution of concepts included in the circle
  - brightness represents interconnectedness of concepts in the circle

\* The following describes the approach used with Leximancer.



# CMMI-ACQ Thematic Structure



# High Ranking Concepts

Ranked Concept List

Concept	AbsoluteRelative	
	Count	Count
<u>process</u>	2068	100%
<u>project</u>	845	40.8%
<u>organization</u>	815	39.4%
<u>product</u>	812	39.2%
<u>supplier</u>	671	32.4%
<u>performance</u>	536	25.9%
<u>work</u>	510	24.6%
<u>management</u>	504	24.3%
<u>agreement</u>	493	23.8%
<u>information</u>	474	22.9%
<u>plan</u>	450	21.7%
<u>Requirements</u>	417	20.1%
<u>measures</u>	374	18%
<u>acquirer</u>	361	17.4%
<u>risk</u>	345	16.6%
<u>practices</u>	343	16.5%
<u>standard</u>	308	14.8%
<u>improvements</u>	295	14.2%
<u>activities</u>	291	14%
<u>level</u>	290	14%
<u>Quality</u>	259	12.5%
<u>results</u>	257	12.4%
<u>Data</u>	254	12.2%
<u>organizational</u>	253	12.2%
<u>defined</u>	248	11.9%
<u>stakeholders</u>	240	11.6%
<u>selected</u>	235	11.3%
<u>Criteria</u>	234	11.3%
<u>established</u>	224	10.8%
<u>support</u>	220	10.6%
<u>analysis</u>	214	10.3%
<u>changes</u>	209	10.1%
<u>models</u>	194	9.3%
<u>action</u>	194	9.3%
<u>service</u>	193	9.3%
<u>reviews</u>	189	9.1%

The most frequent CMMI-ACQ concepts are listed at the left.

The absolute count is the number of text blocks where a given concept occurs.

The relative count is the percentage of text blocks where it occurs.

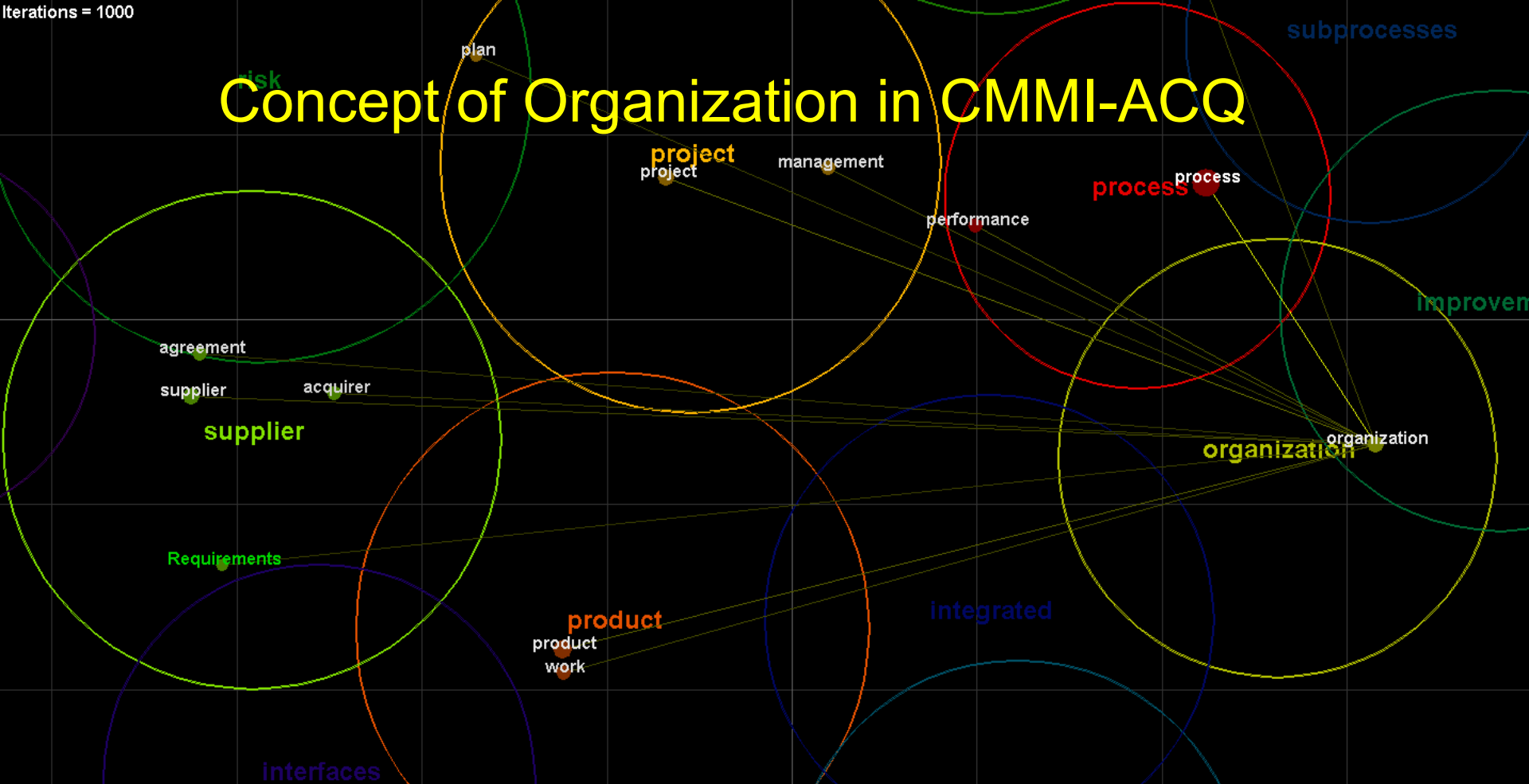
Not surprisingly for a process model, conceptual traces of **process** are found in all of the CMMI-ACQ text blocks.

**Project** and **organization** are the next most significant thematic concepts.

These are followed by **product** and then **supplier all of which are important to the points that follow**

All are in the top 10% of concepts appearing in concept maps that follow.

# Concept of Organization in CMMI-ACQ



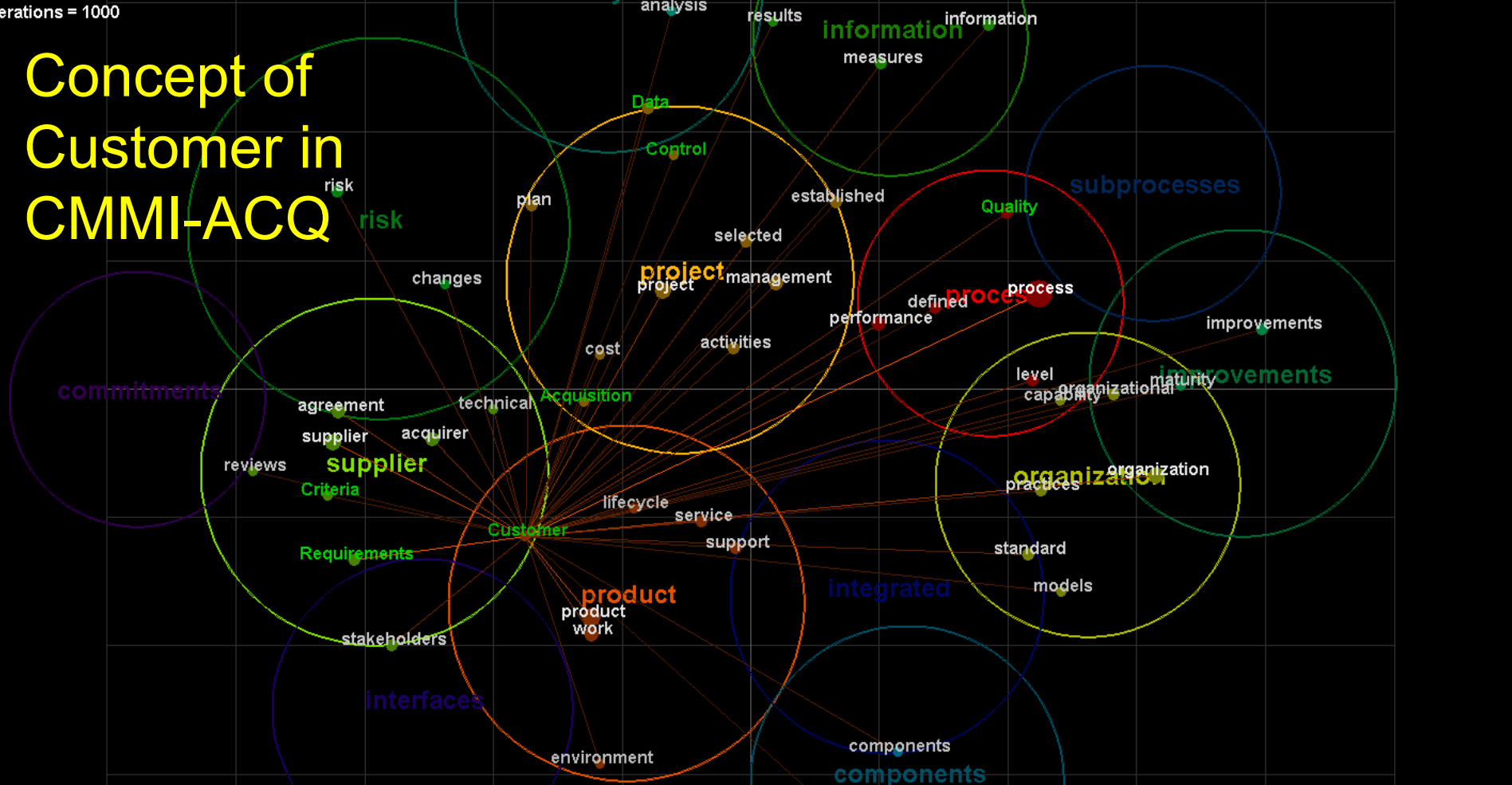
The concept map shows the **top 10%** of the most frequent and connected concepts.

Like all CMM models, **process**, **product** and **project** all come under the purview of a **single organization**.

The model does not cover **changing sponsorship** and **multiple organizational** perspectives needed for **requirements** practice to be in accord with JCIDS.

With respect to **requirements**, **organization** is most frequently focused on **agreement** with the **supplier** – not **customer** or **users**.

# Concept of Customer in CMMI-ACQ



The **customer** concept appears when the top 36 percent of concepts is shown.

**Customer** appears only as a concept in the overlap between the **supplier** and **product** themes and is relatively frequently linked with **Requirements**.

At this point neither **users** nor **validation** yet appear as a basis for validating **Requirements**.





# Customer and Users are not Themes

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Unlike the **supplier** and the (acquisition) **organization**, neither **customer** nor **users** are concepts that are also themes.

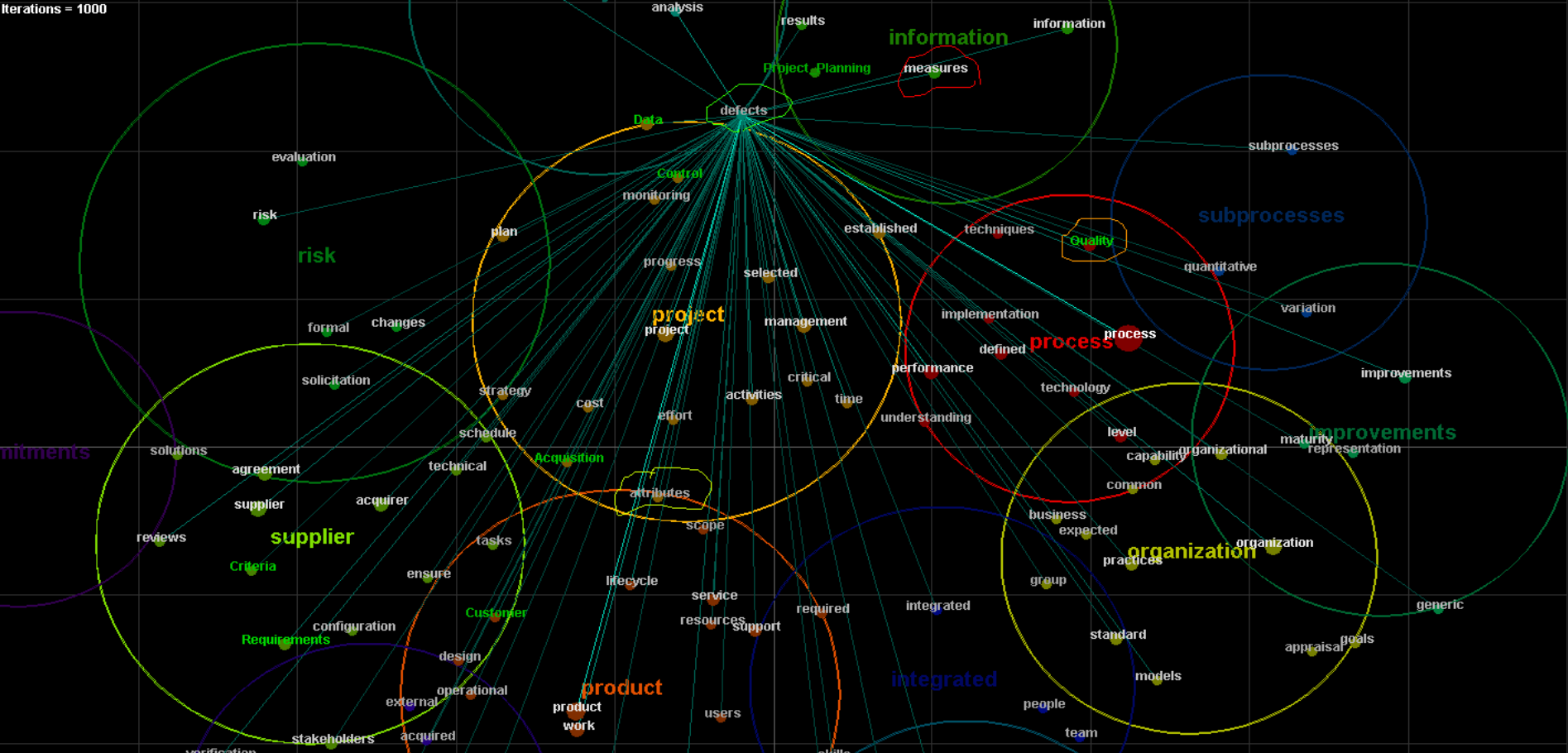
- CMMI-ACQ could be articulated in such a way that **customer** and/or **users** would be just as well connected to other concepts as is **supplier**...
  - thereby becoming a theme or themes
- The acquisition **organization** should give equal consideration to both.

But the CMMI-ACQ is already 400+ pages and this would make it bigger.

- As in the case of dealing with shifting sponsorship and multiple organizations, perhaps another Model or Guide can cover this.
- No one model can satisfy all perspectives.

A **meta-model** may be needed showing where gaps in one model may be covered by another.





The coverage of “quality attributes” in the model is quite minimal – attribute appears at 81%:

- Defect measures are cited as examples of quality attributes in Quantitative Project Management, but “quality attribute” has a different meaning in this context than in standard quality models.
- A characterization of quality attribute is expressed as a factor to consider when formulating customer requirements, but is not repeated again.

It may be worthwhile for the model to cross-reference quality models as a bridge between product and process quality.



# Applying Content Analysis for Improvement of Requirements Development 1

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By identifying misalignments in

- policy
- requirements specifications
- problem and field reports

***content analysis may facilitate identification & resolution of problems***

- ***to support early consideration, articulation and operationalization of usability and other quality attributes***

Content analysis may provide sufficient basis to sub-categorize ***usability*** several levels down where it might be characterized in scenarios for a given context of use.

The range of acceptable or desired responses, whether

- Operational
- System
- Software
- System of Systems

can be quantified and used as a basis for tradeoff analysis and prioritization.



# Applying Content Analysis in Improvement of Requirements Development 2

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Content analysis can map out a conceptual space that can be used to formulate new quality attributes specifically applicable to a context of use

- Providing a richer bases for validation of architectures and products
  - o whether at the operational, systems, subsystems or systems of systems levels.

Formulation of such context specific quality attributes might benefit from additional formalization and computational support enabling

- cross-referencing to higher level quality and process models
- indexing to requirements specifications and problem reports.



# Meta-Modeling to Tailor & Combine Models for Use in Practice

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By identifying misalignments between

- Policy and Practice on the one hand

and

- Process and Quality Models on the other,

***content analysis can facilitate tailoring and combining process and quality models that cover each other's gaps in different contexts of use.***

This is tantamount to creating a meta-model that cross-references

- quality models like those described in ISO 9126 for software architectures
- process models like CMMI-ACQ
- guides like the current draft of the System of Systems System Engineering Guide.



# Thank you for your attention!

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