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# INCOSE Systems Engineering Competency Assessment Guide Systems Modeling Language (SysML) Model Description

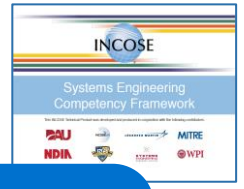
# Purpose of Study

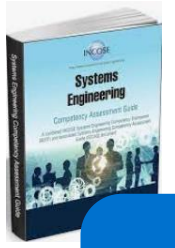
- The INCOSE Systems Engineering Competency Framework (SECF), published in 2018, provides a set of competence requirements for 37 systems engineering competencies against 5 competence levels
- The INCOSE Systems Engineering Competency Assessment Guide (SECAG), published 2023, provides a sample evaluation criteria against each SECF requirement.
- This paper describes the development of a Systems Modeling Language (SysML) model that provides a digital representation of the SECF/SECAG architecture framework.
- SECF/ SECAG databases have been loaded into this structure to form a digital single source of truth representation of the INCOSE SECF / SECAG publications
- A description of the metamodel and data structure is presented as well as a tailoring approaches for use and a series of evolving model use cases.

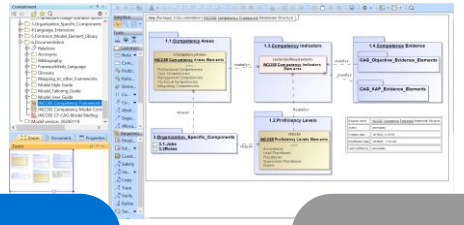
# Outline of Brief

- Framework and Model Development Timeline
- Framework Structure
- Metamodel Structure
- Model Walkthrough
- Open actions
- Future Plans

# Competency Framework Timeline



**2011**

- CWG started work on SECF
- Earlier INCOSE UK Frameworks served as reference

**2018**

- **INCOSE SECF published** as collaboration between 2 professional societies, 12 corporations, 4 academic institutions, and 1 research center
- INCOSE-TP-2018-002.01.0

**2019**

- Work starts on follow on Competency Assessment Framework
- Vision starts for planning digital version of SECF

**2021**

- Work starts on coordination with PDP
- Work continues on follow on Competency Assessment Framework

**2023**

- **INCOSE Competency Assessment Guide published through Wiley**
- **SysML Cameo Systems Modeler model developed**
- **INCOSE IS24 SysML Model Paper submitted (Oct)**
- Plan for implementation within INCOSE SE Lab (fall)

**Future**

- Plans for additional competencies, model use cases, user interfaces

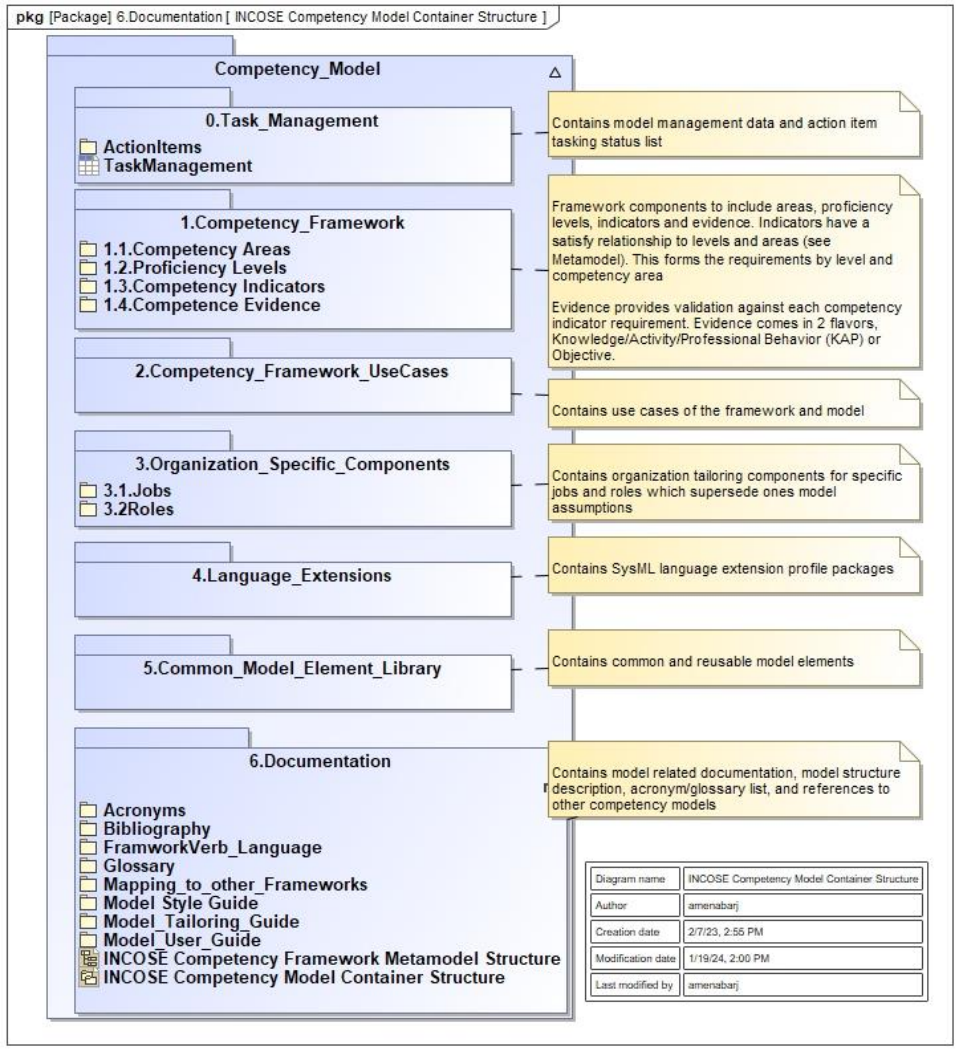
# Definitions Background

| Term | Definition |
|---|---|
| Competency | A measure of an individual's ability in terms of their knowledge, skills, and behavior to perform a given role (Holt and Perry, 2011) , (International Council on Systems Engineering, 2023a) |
| Competence | A measure of specified ability (INCOSE 2015) (International Council on Systems Engineering, 2023a) |
| Framework | Broad overview, outline or skeleton of interlinked items which support a particular approach to a specific objective and serves as guide that can be modified as required by adding or deleting items (International Council on Systems Engineering, 2023a) |
| Proficiency Level | Levels of increasing competence including awareness, supervised practitioner, practitioner, lead practitioner, expert (International Council on Systems Engineering, 2023a) |
| Role | A role is a recognized organizational position, usually performed in exchange for payment. Historically the term "job" and "role" have been used interchangeably, more recently a distinction has appeared. A job comprises all, or parts of one or more defined roles which govern organizational processes and activities. An individual may remain in the same "job" for a long period, but during this time will usually perform multiple roles. (International Council on Systems Engineering, 2023a) |

# Model Development Value Proposition

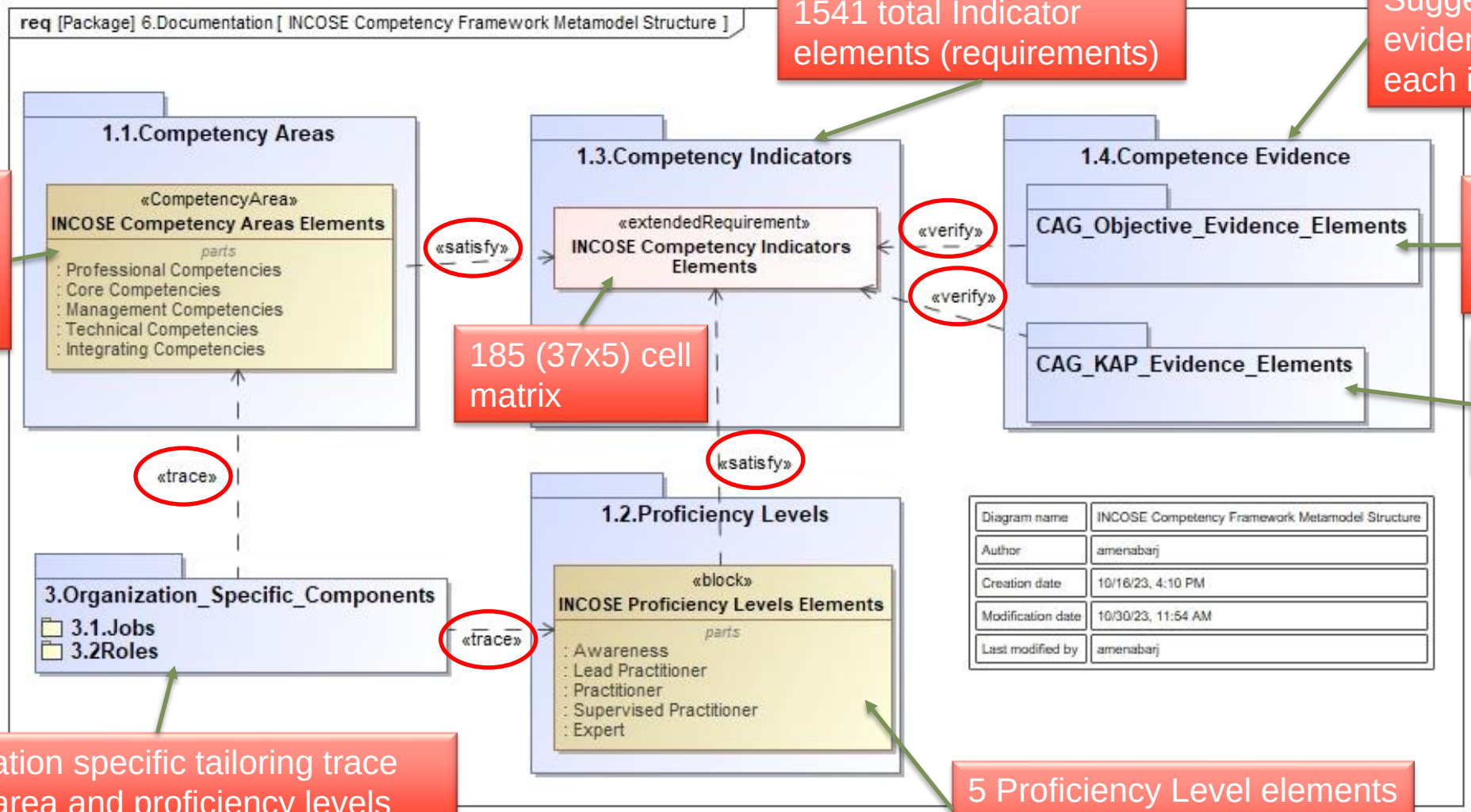
- Provides a dynamic single source of truth baseline for framework maintenance and development
- Allows for exploration of new framework areas and incorporation of other framework databases
  - Developing configuration management process
- “Use Case” development for exploration of various framework applications
  - 13 use cases under development
- Development of tailored models for organizations
  - With role and job definitions mapped to framework

# Model Organization




- Model organized into containers for ease of configuration management, maintenance, and development
- Task Management contains information about model management and prioritized dynamic development task list
- Language Extensions contains model specific SysML extensions
- Common Element Library contains model elements common across the model organization
- Documentation contains model dynamic documentation and PowerPoint presentation templates for auto generation

# SysML Metamodel




37 Area elements satisfy requirements

1541 total Indicator elements (requirements)

Suggested evidence for each indicator

185 (37x5) cell matrix

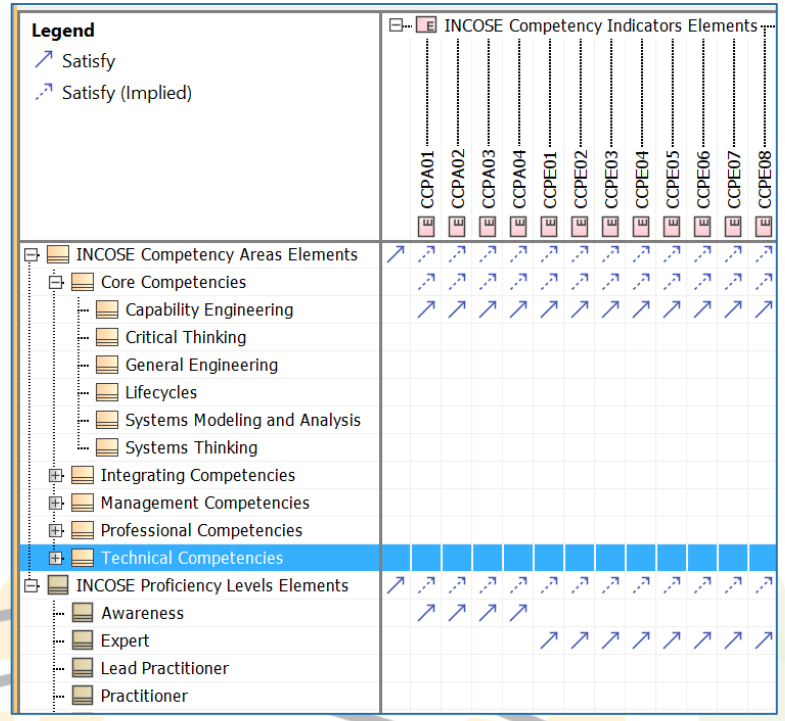
3081 Objective Evidence elements verify requirements

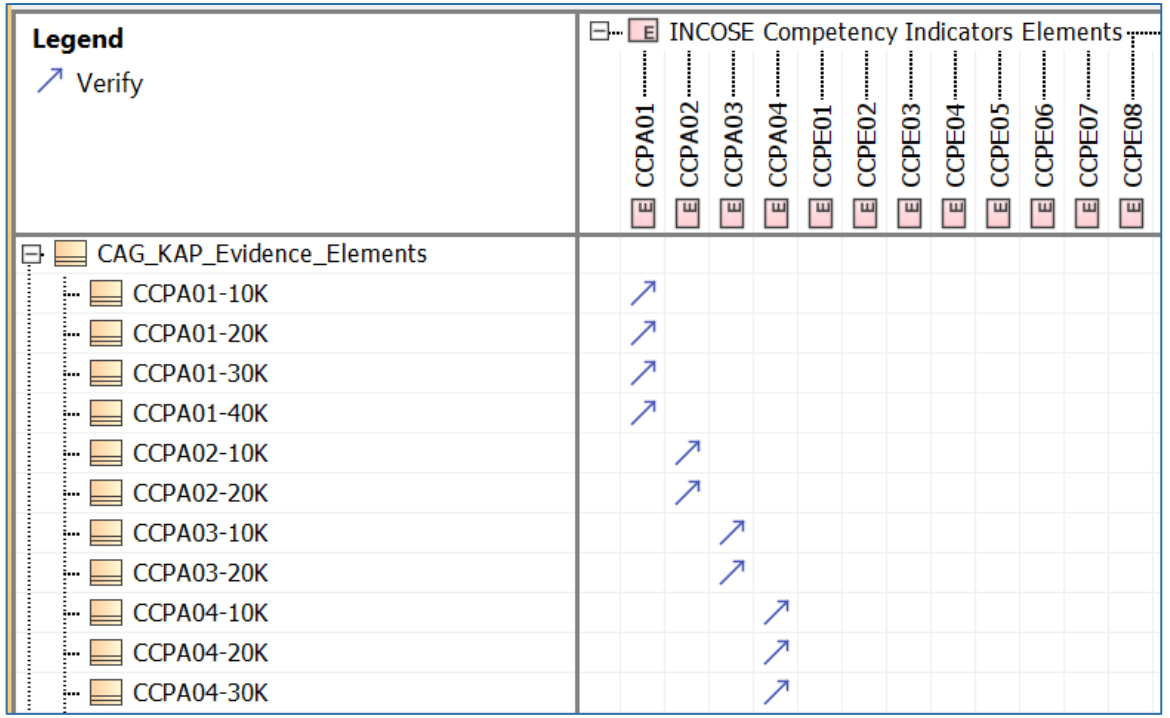
4751 KAP Evidence elements verify requirements

Organization specific tailoring trace back to area and proficiency levels

5 Proficiency Level elements satisfy requirements

# Model Associations




- SysML model associates model elements through satisfy and verify relationships

# Sample Indicator Database Table

| # | Name | Text | Satisfied By |
|---|---|---|---|
| 1 | CGEA01 | Explains core principles of science and mathematics applicable to engineering. [CGEA01] | Awareness<br>General Engineering |
| 2 | CSTS01 | Defines the properties of a system. [CSTS01] | Supervised Practitioner<br>Systems Thinking |
| 3 | CSTA01 | Explains what "systems thinking" is and explains why it is important. [CSTA01] | Awareness<br>Systems Thinking |
| 4 | CSTA02 | Explains what "emergence" is, why it is important, and how it can be "positive" or negative" in its effect upon the system as a whole. [CSTA02] | Awareness<br>Systems Thinking |
| 5 | CSTA03 | Explains what a "system hierarchy" is and why it is important. [CSTA03] | Awareness<br>Systems Thinking |
| 6 | CSTA04 | Explains what "system context" is for a given system of interest and describes why it is important. [CSTA04] | Awareness<br>Systems Thinking |
| 7 | CSTA05 | Explains why it is important to be able to identify and understand what interfaces are. [CSTA05] | Awareness<br>Systems Thinking |
| 8 | CSTA06 | Explains why it is important to recognize interactions amongst systems and their elements. [CSTA06] | Awareness<br>Systems Thinking |
| 9 | CSTA07 | Explains why it is important to understand purpose and functionality of a system of interest. [CSTA07] | Awareness<br>Systems Thinking |
| 10 | CSTA08 | Explains how business, enterprise and technology can each influence the definition and development of the system and vice versa. [CSTA08] | Awareness<br>Systems Thinking |
| 11 | CSTA09 | Explains why it may be necessary to approach systems thinking in different ways, depending on the situation, and provides examples. [CSTA09] | Awareness<br>Systems Thinking |
| 12 | CSTS02 | Explains how system behavior produces emergent properties. [CSTS02] | Supervised Practitioner<br>Systems Thinking |

- 1541 model elements

- Indicators modeled in SysML as requirements
- Proficiency levels and competency areas are each individual model elements
- 185 matrix cells (37 Area x 5 Proficiency Level), each containing multiple indicator elements (1541 indicator requirement elements)
- Each requirement is satisfied by proficiency levels and competency area
- Each requirement is verified by KAP and Objective evidence model elements

# Sample SECAG KAP Evidence Database Table

| # | Name | CAG_ Evidence_ Text | Verifies |
|---|---|---|---|
| 1711 | MCML04-10P | (P) Uses facilitation skills in project/program reviews to ensure Systems Engineering processes addresses enterprise-level Configuration Management issues and vice versa. [MCML04-10P] | MCML04 |
| 1712 | MCML04-20A | (A) Advises on high value, high risk or high opportunity enterprise-level Configuration Management review issues. [MCML04-20A] | MCML04 |
| 1713 | MCML04-30A | (A) Persuades stakeholders to address enterprise-level Configuration management issues. [MCML04-30A] | MCML04 |
| 1714 | MCML05-10A | (A) Analyzes causes of baseline inconsistency on projects of various complexity. [MCML05-10A] | MCML05 |
| 1715 | MCML05-20P | (P) Fosters agreement between key stakeholders at enterprise level to resolve baseline consistency issues, by promoting a holistic viewpoint. [MCML05-20P] | MCML05 |
| 1716 | MCML06-10A | (A) Analyzes impact of major changes . [MCML06-10A] | MCML06 |
| 1717 | MCML06-20A | (A) Persuades stakeholders to change strategy in order to reduce the potential impact of change. [MCML06-20A] | MCML06 |
| 1718 | MCML07-10P | (P) Coaches or mentors practitioners across the enterprise in competency-related techniques, recommending development activities. [MCML07-10P] | MCML07 |
| 1719 | MCML07-20A | (A) Develops or authorizes enterprise training materials in this competency area. [MCML07-20A] | MCML07 |
| 1720 | MCML07-30A | (A) Provides enterprise workshops/seminars or training in this competency area. [MCML07-30A] | MCML07 |
| 1721 | MCML08-10A | (A) Analyzes different approaches across different domains through research. [MCML08-10A] | MCML08 |
| 1722 | MCML08-20A | (A) Defines novel approaches which could potentially improve the SE discipline within the enterprise. [MCML08-20A] | MCML08 |
| 1723 | MCML08-30P | (P) Fosters awareness of these novel techniques within the enterprise. [MCML08-30P] | MCML08 |

- KAP entries are individually categorized by each KAP type
- Each entry is linked to an indicator requirement through a verification relationship

- 4751 model elements

# Sample CAG Objective Evidence Database Table

| # | Name | CAG_ Evidence_ Text | Verifies |
|---|---|---|---|
| 1 | CSTS01-E10 | Concept map or other model of a system. [CSTS01-E10] | CSTS01 |
| 2 | CSTS01-E20 | System concept document defining system lifecycle, context, hierarchy, sum of parts, purpose, boundary and key interactions. [CSTS01-E20] | CSTS01 |
| 3 | CCPE01-E10 | Published papers or books etc. on new technique in refereed journals/company literature. [CCPE01-E10] | CCPE01 |
| 4 | CCPE01-E20 | Published papers in refereed journals or internal literature proposing new practices in this competence area (or presentations, tutorials etc.). [CCPE01-E20] | CCPE01 |
| 5 | CCPE01-E30 | Own proposals adopted as industry best practices in this competence area. [CCPE01-E30] | CCPE01 |
| 6 | CCPE02-E10 | Records demonstrating internal or external advisory or consultative role in capability engineering and management. [CCPE02-E10] | CCPE02 |
| 7 | CCPE03-E10 | Records demonstrating internal or external advisory or consultative role in capability engineering and management. [CCPE03-E10] | CCPE03 |
| 8 | CCPE03-E20 | Records of advice provided together with evidence that the issues advised on were by their nature either complex or sensitive. [CCPE03-E20] | CCPE03 |
| 9 | CCPE04-E10 | Records demonstrating internal or external advisory or consultative role in capability engineering and management. [CCPE04-E10] | CCPE04 |
| 10 | CCPE05-E10 | Research records. [CCPE05-E10] | CCPE05 |
| 11 | CCPE05-E20 | Published papers in refereed journals on this topic. [CCPE05-E20] | CCPE05 |
| 12 | CCPE05-E30 | Published articles or books etc.. [CCPE05-E30] | CCPE05 |

- Objective entries are individually categorized
- Each entry is linked to an indicator requirement through a verification relationship

- 3081 model elements

# KAP and Objective Evidence Database Table

| # | Name | CAG Area Name | CAG Area Category | CAG Area Description | CAG Area Why it Matters | CAG Types of Evidence | CAG Learning and Development | CAG Indicator | CAG_ Evidence_ Text | CAG_ Evidence_ Satisfied |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CSTS01-E10 | Systems Thinking | Core Competencies | The application of the fundamental concepts of systems thinking to Systems Engineering. These concepts include understanding what a system is, its context within its environment, its boundaries and interfaces, and that it has a lifecycle. System thinking applies to the definition, development and production of systems within an enterprise and technological environment and is a framework for curiosity about any system of interest. | Systems thinking is a way of dealing with increasing complexity. The fundamental concepts of systems thinking involve understanding how actions and decisions in one area affect another, and that the optimization of a system within its environment does not necessarily come from optimizing the individual system components. Systems Thinking is conducted within an enterprise and technological context. These contexts impact the lifecycle of the system and place requirements and constraints on the systems thinking being conducted. Failing to meet such constraints can have a serious effect on the enterprise and the value of | Any combination of the types of evidence may be acceptable (depending on how the Framework is tailored and used). | The INCOSE Professional Development Portal provides example guidance on how to gain an initial awareness of a competency area and options for developing further competence thereafter. | CSTS01 | Concept map or other model of a system. [CSTS01-E10] | false |
| 2 | CSTS01-E20 | Systems Thinking | Core Competencies | The application of the fundamental concepts of systems thinking to Systems Engineering. These concepts include understanding what a system is, its context within its environment, its boundaries and interfaces, and that it has a lifecycle. System thinking applies to the definition, development and production of systems within an enterprise and technological environment and is a framework for curiosity about any system of interest. | Systems thinking is a way of dealing with increasing complexity. The fundamental concepts of systems thinking involve understanding how actions and decisions in one area affect another, and that the optimization of a system within its environment does not necessarily come from optimizing the individual system components. Systems Thinking is conducted within an enterprise and technological context. These contexts impact the lifecycle of the system and place requirements and constraints on the systems thinking being conducted. Failing to meet such constraints can have a serious effect on the enterprise and the value of | Any combination of the types of evidence may be acceptable (depending on how the Framework is tailored and used). | The INCOSE Professional Development Portal provides example guidance on how to gain an initial awareness of a competency area and options for developing further competence thereafter. | CSTS01 | System concept document defining system lifecycle, context, hierarchy, sum of parts, purpose, boundary and key interactions. [CSTS01-E20] | false |

Evidence Element ID

Area Information

Satisfied requirement ID
Evidence text
Boolean check on satisfaction

Table organization mirrors SECF / SECAG publication tables

# Model Allows for Organization Tailoring

| # | Name | Organization_ Role_ Purpose | Organization_ Role_ Activity | Organization_ Role_ Level | Organization_ Role_ Constraint | Required Competencies |
|---|---|---|---|---|---|---|
| 1 | Sample_Organization_Role (a) | Configuration Manager | Perform configuration management and maintain configuration items. Provide reports on configuration control and conduct audits. | Responsible | Conforms to program requirements and organization standards | Configuration Management<br>Expert |
| 2 | Sample Organization Role (b) | Configuration Manager | Perform configuration management and maintain configuration items. Provide reports on configuration control and conduct audits. | Responsible | Conforms to program requirements and organization standards | Communications<br>Practitioner |
| 3 | Sample Organization Role (c) | Configuration Manager | Perform configuration management and maintain configuration items. Provide reports on configuration control and conduct audits. | Responsible | Conforms to program requirements and organization standards | Team Dynamics<br>Lead Practitioner |
| 4 | Samle Organization Role (d) | Configuration Manager | Perform configuration management and maintain configuration items. Provide reports on configuration control and conduct audits. | Responsible | Conforms to program requirements and organization standards | Systems Thinking<br>Awareness |

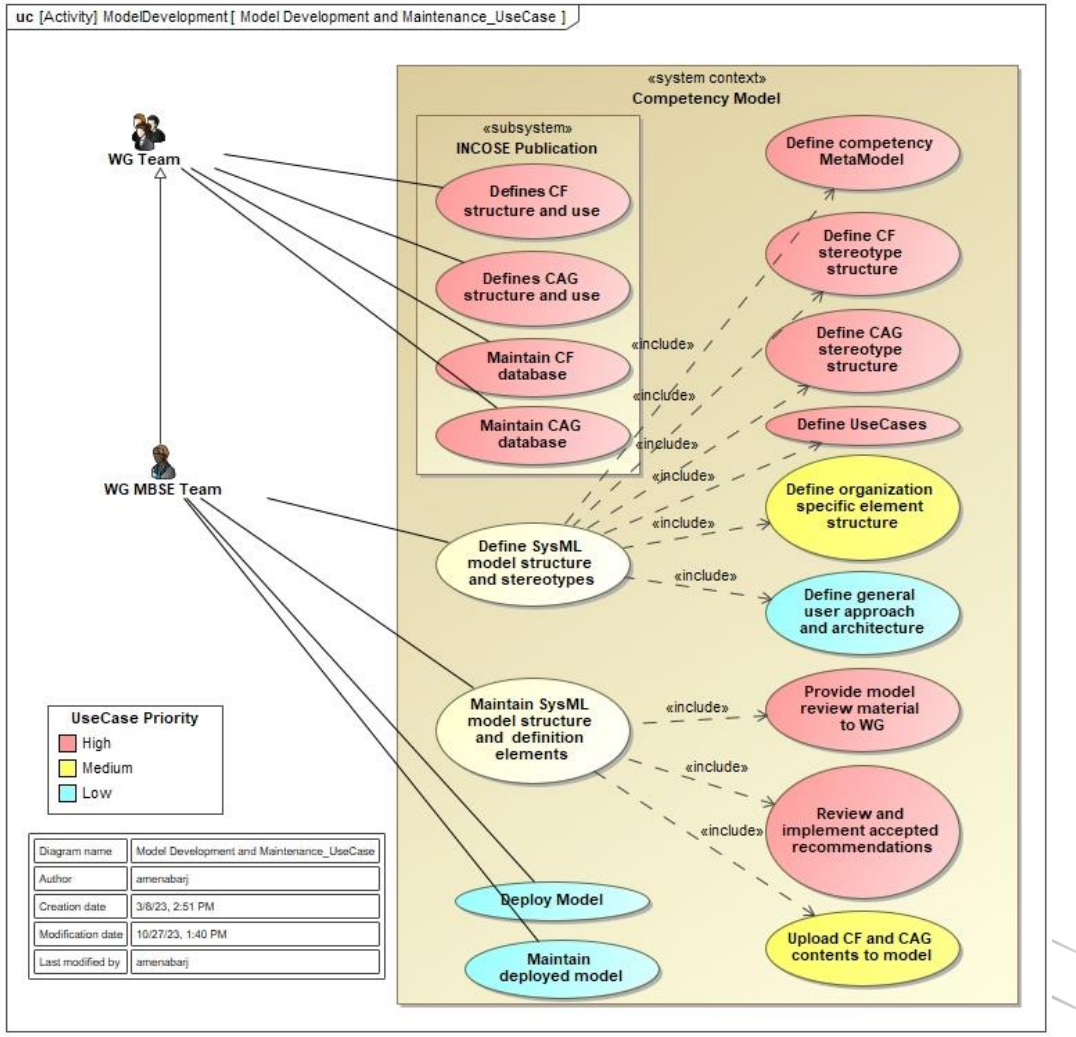
- Jobs and roles particular to an organization can be created and mapped to existing model elements
- Allows for model tailoring to a particular organization
- Example shows a role, broken into 4 parts, mapped to required competency and competence level

# Current Model Use Cases

| # | Name | Documentation |
|---|---|---|
| 1 | CandidateRecruitment | Having defined the requirements for a role in terms of competencies, an employer can assess candidate competence against the required competencies using the Competency Framework assessment guide. This helps to provide an objective (and repeatable) assessment of candidates at interview |
| 2 | CareerPath | An employer can link career paths within the organization to differing expected combinations of competencies and associated minimum competence levels. This can be used to provide insight to employees as to the competence needs for differing career development paths. This indicates the competencies and levels necessary to progress a selected career path – informing employee career development choices along the way. |
| 3 | CourseCurricula | An educational curriculum provider interacts with curriculum sponsors and/or accreditation agencies to assess the effectiveness of an educational course/module in delivering stated outcomes against pre-defined accreditation objectives. This might be through assessment of learning objectives against competency needs, and outcomes against competence acquired or those attending the course |
| 4 | DevelopmentPlanning | An employee can "self-assess" their skills against the competency framework, using the assessment guidance provided. This helps inform their career development choices – whether as part of a job application or more generally as part of a personal career path development. |
| 5 | EducationalCourses | A company recruiter or capability manager interacts with a representative of an educational institution to define the competencies expected from those leaving the educational institution. This helps align program content to better prepare graduates for company employment. |
| 6 | EducationalVerification | A company recruiter or capability manager interacts with a representative of an educational institution to assess and recruit pre-qualified students against a set of competency needs for a company pipeline programs. |
| 7 | JobDescription | An employer publishes the requirements for an organizational role in terms of competencies and their minimum required levels – as defined above. Candidates and recruiting agencies can compare this against their own (or their candidates') competences to determine their suitability for the position. It also supports candidate preparation as it provides an insight into the evidence they may be asked to provide during their application and/or interview. |
| 8 | ModelDevelopment | SysML digital representation of INCOSE framework database and structure development and maintenance |
| 9 | ModelUsage | SysML digital representation of INCOSE framework utilization by INCOSE Competency Work Group members and/or other users |
| 10 | PerformaceAssessment | An employer sets targets for individual competence attainment in one or more competencies, and provides opportunities for competency development to occur. The competence assessment activity can be used to formally gauge competence level attainment against the targets set, as an input to their overall performance rating. |
| 11 | RoleDescription | An employer defines the needs for an organizational role in terms of competencies and their minimum required levels. This use case is elaborated further in the section on role definitions elsewhere in this document. A competency-driven job definition can also help ensure that the requirements for a role are based upon ability rather than age and thus aligns with age-discrimination legislation in areas such as the European Union (GOV. UK 2017). |
| 12 | TrainingInvestment | An organization gathers enterprise-wide data through individual employee competence assessment against the framework and uses this to assess organizational-level strengths and weaknesses. This enables training investment to be focused on areas deemed organizationally (and individually) in areas where it is needed most. |
| 13 | WorkForceRiskAnalysis | An organization can use information gathered through individual employee competency assessment against the framework to analyze organizational capability within a specific domain of Systems Engineering, or more generally. This could be driven by current or future business aspirations. Acquirers (i.e. organizations placing contracts) could mandate minimum organizational capability requirements for those supporting a contract/task as a risk reduction strategy – requesting capability data based upon competency assessments using the framework rather than traditional more generalized experiential statements from a business. |

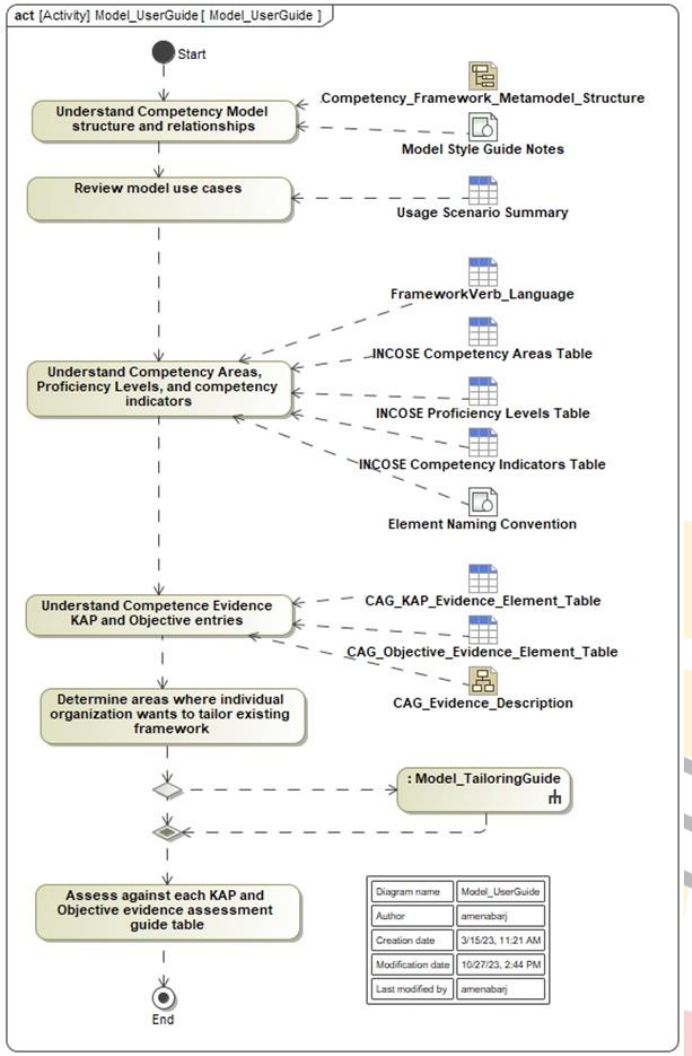
- 13 use cases currently being evaluated in the model
- Additional use cases and model behaviors under investigation

# Sample Model Use Case – Model Development




- Model development use case covers Competency WG team usage as well as the MBSE development sub team (members of the WG)
- Primary utilization is to have a digital single source of truth framework and database which aids in the development and advancement of future frameworks and addition of other databases

# Sample Model Documentation




- Imbedded model documentation includes user guide, tailoring guide, style guide, acronyms, abbreviations, self generating briefing, INCOSE paper

# Model Development Management

| # | Body | Annotated Element | Documentation | ActionAssignedTo | ActionStatus | ActionDueDate | ActionCompleteDate |
|---|---|---|---|---|---|---|---|
| 1 | Expand Use Cases | 2.Competency_Framework_UseCases | Expand use cases based on ones there and new ones | unassigned | NotStarted | 20231201 | |
| 2 | Create mapping of areas to other competency models and INCOSE areas | Mapping_to_other_Frameworks | Map model CF and CAG appropriate tags to other models and INCOSE SE competency areas | unassigned | NotStarted | 20230505 | |
| 3 | Load Competency Area Why it Matters | INCOSE Competency Areas Elements | Load why it matters language from CAG source | J. Amenabar | Complete | 20231201 | 20231228 |
| 4 | Load Competency Area description field from CAG | INCOSE Competency Areas Table | Load description from CAG for each competency area to documentation field in table. NOTE: Owner Documentation column is a metachain and should NOT be modified. | J. Amenabar | Complete | 20231201 | 20231228 |
| 5 | Load possible contributory types of evidence from CAG | INCOSE Competency Areas Table | Load contributory types of evidence field entries from CAG into appropriate column in table. NOTE: Owner Documentation column is a metachain and should NOT be modified. | J. Amenabar | Complete | 20231201 | 20231228 |
| 6 | Load CAG Learning and Development | INCOSE Competency Areas Table | Load CAG Learning and Development into appropriate column in table. NOTE: Owner Documentation column is a metachain and should NOT be modified. | J. Amenabar | Complete | 20231201 | 20231228 |
| 7 | Load CF requirements (indicators) from CAG | INCOSE Competency Indicator Satisfy | Load entries from INCOSE CAG document database as well as area and proficiency level it satisfies | J. Amenabar | Complete | 20230615 | 20231228 |
| 8 | Load KAP verification items from CAG | | Load KAP evidence from CAG following KAP stereotype | J. Amenabar | Complete | 20231201 | 20231228 |
| 9 | Load objective evidence from CAG | | Load objective evidence from CAG following KAP stereotype | J. Amenabar | Complete | 20231201 | 0231228 |
| 10 | Develop use case diagrams from CAG table listing | 2.Competency_Framework_UseCases | Develop use cases for outlined SECAG document usages | J. Amenabar | Complete | 20230324 | 20231027 |
| 11 | Add activity diagram for model usage | Model_Tailoring_Guide | create activity diagram for usage of model. tailoring is a different activity diagram which could be included or referenced. Use 2022 paper on the use of CF. | J. Amenabar | Complete | 20230501 | 20231027 |
| 12 | Add activity diagram for organization tailoring | Model_Tailoring_Guide | Develop activity diagram outlining how an organization might tailor the process. Use tailoring approach outlined in documents. | J. Amenabar | Complete | 20230701 | 20231027 |

- Action item stereotype allows tracking of internal development task
- Developing model utilization and maintenance rules for configuration management

# Summary

- Model framework structure (metamodel) has been implemented
- SECF / CAG databases imported
- Use case scenarios generated and under evaluation
- Model framework configuration management under study for possible structural upgrades if required
- Incorporation of additional framework databases from other areas such as digital engineering, security is an area of interest
- Development of a user interface to facilitate self-assessment with the model is a longer-term project of interest

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hybrid event

Dublin, Ireland
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