An overview of INCOSE Certification and the Systems Engineering Handbook

INCOSE Western Cape
17 July 2014
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• This briefing was created from information from various INCOSE sources as indicated in the Notes section of this slide.
Presentation Overview

• Introduction and goals
• The value of INCOSE certification
• Requirements for various certification types
• The CSEP/ASEP certification process and maintenance of your status
• The CSEP/ASEP exam
• A brief overview of the handbook structure and content
• Sample Exam Questions
• Questions
The value of INCOSE certification
What Is INCOSE Certification?

**What is Certification**

Certification is an **occupational designation**

- Provides confirmation of an individual's qualifications (specific knowledge and/or skill level) in a specified profession or occupational specialty
- **Certification is a formal process**
  - Issued by an organization
- **Certification is voluntary**
  - It is neither a barrier nor a gate to entering a job
  - However, it may be used as a qualifier in placement

INCOSE Certifies professionals in the discipline of Systems Engineering
Certification Background and History

• 2001: Research started
• March 2004: CSEP established
• 2008: SEH V3.1 (ISO/IEC 15288), ASEP, CSEP Acq
• 2010: SEH V3.2 (ISO/IEC15288 update), ESEP
• 2014: CSEP Acq retired
• May 2015: SEH V4.0
Why is Certification Important?

• To You
  • Formally recognizes your Systems Engineering capabilities
  • Distinguishes you from others within your professional field
  • Can provide a competitive advantage in your career
  • Provides a portable Systems Engineering designation that is recognized across industry
  • Furthers your professional development as a systems engineer

INCOSE Certification sets you and your organization apart!
Why is Certification Important?

- To your organization...
  - Formally recognizes the Systems Engineering capabilities of your people
  - Can provide a competitive discriminator for your proposals
  - Can be used as part of the hiring process
  - Provides an independent internal and external assessment
  - Helps advance the state of the art and practice of Systems Engineering

INCOSE Certification sets you and your organization apart!
Annual Growth

Growth Per Type Per Year

- CSEP
- ASEP
- ESEP
Total Growth

Total Growth Per Type

- CSEP
- ASEP
- ESEP

Year:
- 2004: CSEP 12, ASEP 19, ESEP 42
- 2005: CSEP 11, ASEP 54, ESEP 114
- 2006: CSEP 11, ASEP 78, ESEP 193
- 2007: CSEP 263, ASEP 332, ESEP 380
- 2008: CSEP 404, ASEP 1235, ESEP 1399

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Requirements for Various Certification Types
# Requirements for Certification Types

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>Experience</th>
<th>Education</th>
<th>References</th>
<th>Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None Required</td>
<td>None Required</td>
<td>None Required</td>
<td>Same Exam as CSEP</td>
</tr>
<tr>
<td>ASEP</td>
<td>Minimum 5 years SE experience</td>
<td>Technical Degree (can be augmented with additional years of experience without a technical degree)</td>
<td>3 references (cumulative coverage of the years of experience)</td>
<td>CSEP exam based on INCOSE SE Handbook</td>
</tr>
<tr>
<td>CSEP</td>
<td>Minimum 25 years (20 if CSEP) SE experience</td>
<td>Technical Degree (can be augmented with additional years of experience without a technical degree)</td>
<td>3 references (cumulative coverage of at least the most recent 10 years of experience) Support panel review, if required</td>
<td>No examination, panel review</td>
</tr>
<tr>
<td>ESEP</td>
<td>Minimum 5 years of professional development credit</td>
<td>Technical Degree (can be augmented with additional years of experience without a technical degree)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Certification is open to all people, it is not just INCOSE members.
Guidelines on Distribution SE for CSEP’s

• At least 5 years of SE experience
• More than 1 year in at least 3 of the 14 following systems engineering functional areas:
Systems Engineering Disciplines Recognized for Experience

• Requirements Engineering
• Risk and Opportunity Management
• Baseline Control
• Technical Planning
• Technical Effort Assessment
• Design Development

• Qualification, Verification, and Validation
• Process Definition
• Tool Support
• Training
• System Integration
• Quality Assurance
• Specialty Engineering
• Other
The experience table

- The experience table is optional if you have more than 7 years experience but complete it in any case.
- Cross reference to the rest of the experience section.
- Ensure the requirements for both 1 year+ in 3 areas and 5 years+ in total and are covered.
- Only SE experience.
- Avoid the ‘Other’ work area.

<table>
<thead>
<tr>
<th>Work in Months on Position PX in SE Area</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>Total Months of Effort in Each Work Area</th>
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<tr>
<td>Requirements Engineering</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>15</td>
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<tr>
<td>Risk and Opportunity Management</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
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<td>7</td>
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<tr>
<td>Baseline Control</td>
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<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>0</td>
<td>3</td>
<td></td>
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<tr>
<td>Technical Planning</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
<td>9</td>
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<td>Technical Effort Assessment</td>
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<td>1</td>
<td></td>
<td></td>
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<td>5</td>
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<tr>
<td>Architecture/Design Development</td>
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<td>2</td>
<td></td>
<td></td>
<td>14</td>
<td>1</td>
<td>21</td>
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<td>Qualification, Verification, and Validation</td>
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<td>2</td>
<td></td>
<td></td>
<td>12</td>
<td>2</td>
<td>18</td>
<td></td>
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<tr>
<td>Process Definition</td>
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<td>2</td>
<td>3</td>
<td></td>
<td>1</td>
<td>5</td>
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<td>Tool Support</td>
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<td>Training</td>
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<tr>
<td>Systems Integration</td>
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<td>1</td>
<td>3</td>
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<td>1</td>
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<td>6</td>
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<td>1</td>
<td>3</td>
<td>1</td>
<td>7</td>
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<tr>
<td>Specialty Engineering</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Other</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td>7</td>
<td>0</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Total for All Areas</td>
<td>16</td>
<td>14</td>
<td>22</td>
<td>11</td>
<td>49</td>
<td>5</td>
<td>119</td>
<td></td>
</tr>
</tbody>
</table>
Guidelines on Distribution of Minimum 5 Years of SE Experience in the SE Function Areas for CSEP’s

• Technical Bachelor’s degrees include BS or BSE (or international equivalents)
  — Aeronautical, Astronautical, Electrical, Mechanical, Civil, Chemical, Math, Chemistry, Physics

• If the degree does not come from an ABET (or equivalent) accredited school, then an MS, MSE, or PhD degree in those fields is acceptable. The acceptability of other degrees outside this guideline is subject to the decision of the Certification Program Office

If lacking a technical Bachelor’s degree:
  • minimum of 5 more years of additional engineering experience with Bachelor’s degree, or equivalent, in a non-technical field; or
  • minimum of 10 more years of additional engineering experience with no degree
The CSEP/ASEP Certification Process and Maintenance of your Status.
Certification Process Timeline Diagram

- **Study**: INCOSE SE Handbook

- **Application Development**
  1. Verifiable Education
  2. Verifiable Experience
  3. Applicant’s Advocates (three references knowledgeable about SE)

- **INCOSE Application Center**
  - Submit Completed Application And Fee $%
  - Applicant’s own pace

- **INCOSE Evaluation**
  - Four to six

- **Timeline**

- **Notify Applicant**

- **Pass**
  - Pay test fee
  - Schedule & Take Exam (Prometric Test Center)
  - Applicant has up to one year to pass the test (three tries 3 months apart). **Test is scheduled directly** with Prometric.
  - Applicant’s own pace
## Costs

<table>
<thead>
<tr>
<th>Certification Level</th>
<th>Application Fees</th>
<th>Examination (and Re-Examination Fees, if needed)</th>
<th>Renewal Fees (Tri-Annual, unless noted)</th>
</tr>
</thead>
</table>
| **Entry Level**     | 150 USD (Must be an INCOSE member) | US: 80 USD  
Japan: 165 USD  
Other: 120 USD | 100 USD  
(Pent-Annual)  
Must also maintain INCOSE membership |
| **Transition**      | **ASEP to CSEP** | 200 USD | N/A | N/A |
| **Foundation Level**|                  | 400 USD | US: 80 USD  
Japan: 165 USD  
Other: 120 USD | 150 USD |
| **INCOSE CSEP Member Fee** | 300 USD | US: 80 USD  
Japan: 165 USD  
Other: 120 USD | 100 USD |
| **Senior Level**    | 550 USD (Must be an INCOSE member) | N/A | N/A  
However, must maintain INCOSE membership |
How Long Will It Take to Get Certified?

There is no one answer. Much depends on the applicant.

**Applicant**
- Downloads information from INCOSE web page
- Collects information
- Fills out and submits forms via e-mail
- Pays fee on-line

**References** submit recommendations via e-mail to INCOSE.

**Applicant** submits missing material.

**INCOSE**
- Receives application & fee
- Checks completeness of submittal
- Notifies applicant by e-mail that application was received and is complete or has missing material

**INCOSE**
- Receives recommendations from references and missing information
- Evaluates education and experience
- Notifies applicant of evaluation results. If minimum requirements are met, authorizes exam

**Time for Steps B-F:** Shortest is 37 days, Average is 147 days

- **A. ???????**
- **B. < 2 weeks**
- **C. Averaging 50 days**
- **D. Averaging 21 days**
- **E. Averaging 62 days**
- **F. < 2 weeks**

**INCOSE** sends CSEP certificate via postal mail to applicant.
Renewal Process

1) Throughout your renewal period, perform the professional development activities that earn PDU credit (ASEP 120 PDU every 5 years, CSEP 120 PDU every 3 years)

2) Record your PDU’s in the log form

3) Complete the certification renewal form and pay the renewal fee

4) Email the signed renewal form and PDU log

5) INCOSE will mail you your recertification credentials if the above steps are successfully completed. Note that some people may be required to participate in quality audits as part of the renewal process

www.incose.org
## PDU Units

<table>
<thead>
<tr>
<th>Professional Development Activities</th>
<th>Units Earned</th>
<th>3 / 5 year Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical Society Participation Category</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Be an INCOSE member</td>
<td>5 PDU/year</td>
<td>15 PDU</td>
</tr>
<tr>
<td>Attend Professional Technical Society local event/chapter presentation/exhibit</td>
<td>1 PDU/hour attendance (10 PDU/year limit)</td>
<td>30 PDU</td>
</tr>
<tr>
<td>Attend Professional Technical Society Conference/Symposium</td>
<td>1 PDU/hour attendance (24 PDU/year limit)</td>
<td>72 PDU</td>
</tr>
<tr>
<td>Participate on Professional Technical Society working groups, committees, etc.</td>
<td>1 PDU/hour of effort</td>
<td>No limit</td>
</tr>
<tr>
<td>Perform Leadership Role in Professional Technical Society at local, national or international level</td>
<td>1 PDU/hour of effort</td>
<td>No limit</td>
</tr>
<tr>
<td><strong>SE Course Work &amp; Publication Category</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete a technical graduate level course</td>
<td>2 PDU/class hour</td>
<td>No limit</td>
</tr>
<tr>
<td>Professional Development Activities</td>
<td>Units Earned</td>
<td>3 / 5 year Max</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Attend educational course, tutorial, or seminar</td>
<td>1 PDU/hour</td>
<td>No limit</td>
</tr>
<tr>
<td>Teach professional development coursework, including presentations not part of job function</td>
<td>2 PDU/hour (prep) 1 PDU/hour (teach)</td>
<td>40 PDU</td>
</tr>
<tr>
<td>Write &amp; publish SE article</td>
<td>5 PDU/article</td>
<td>No limit</td>
</tr>
<tr>
<td>Write &amp; publish SE book</td>
<td>30 PDU (primary author)/book 10 PDU (contributing author)/book</td>
<td>No limit</td>
</tr>
<tr>
<td>Attend vendor presentation with educational value</td>
<td>1 PDU/hour attendance 5 PDU/year limit</td>
<td>15 PDU</td>
</tr>
</tbody>
</table>

**SE Job Function Participation Category**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Patent Award</td>
<td>10 PDU/award</td>
<td>No limit</td>
</tr>
<tr>
<td>Serve as designated lead systems engineer for a system, product or service</td>
<td>15 PDU/year</td>
<td>45 PDU</td>
</tr>
<tr>
<td>Lead organization to increase INCOSE systems engineering certifications</td>
<td>5 PDU/year</td>
<td>15 PDU</td>
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</table>
# PDU Example (CSEP)

<table>
<thead>
<tr>
<th>Activity</th>
<th>PDU</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCOSE Member (5 PDU/ Year)</td>
<td>15</td>
</tr>
<tr>
<td>Attending 4 INCOSE Chapter Meetings per year (1.25 hour each)</td>
<td>15</td>
</tr>
<tr>
<td>Attending 2 other professional society meetings (1.25 hours each)</td>
<td>7</td>
</tr>
<tr>
<td>Attending the local INCOSE Conference (8 hours per day, 2 days, 1 per year every year)</td>
<td>48</td>
</tr>
<tr>
<td>Attend one 5 day PPI Training Course</td>
<td>40</td>
</tr>
<tr>
<td><strong>TOTAL (Over 3 years)</strong></td>
<td><strong>125</strong></td>
</tr>
</tbody>
</table>
The CSEP/ASEP exam
Certification Knowledge Requirements

• Exam Basis
  – INCOSE SE Handbook

• Exam is
  – 2 hours in length
  – 120 multiple choice questions
  – Administered electronically at world-wide Prometric locations - Pass/Fail results provided immediately upon exam completion

• Candidates are eligible for two re-tests within one year of application submittal

The INCOSE Systems Engineering Handbook is the basis for the Certification exam
What kind of test is CSEP?

• **NOT** a test of your understanding of **Systems Engineering Principles**
• **NOT** a test of your understanding of **Systems Engineering Standards**
• **SEH is the only source**
• 50% Recall/Recognition (In order to pass the CSEP exam you need to recognize key phrases and language of the SEH)
• 50% Comprehension (You need a good understanding of the purpose of each process and tool, its elements and the position it has in the life cycle sequence)
Anatomy of a question

• Multiple Choice
• Single Answer Questions, Multiple Answer Questions

Q: What is the aim of the resource management process?

- A. To establish the resource needs for a project
- B. To keep track of where resources are in the building
- C. To create and maintain a pool of resources for a project
- D. To decide which resource is allocated to which project element

Detractor (s)

Throw Away

Single Answer
Anatomy of a question

• Multiple Answer Questions

Q: What are two inputs of the Verification Process? (choose 2)

☑ A. Updated Requirements Verification and Traceability Matrix
☑ C. Integrated System
☑ D. Updated Requirements

☐ B. Verification Procedure

Multiple Answers

Detractor(s)

Throw Away
Q: Which of the following are valid definitions for Systems Engineering? (Choose 3)

- A. Systems engineering is a discipline that concentrates on the design and application of the whole (system) as distinct from the parts.
- B. Systems Engineering is characterized by a systematic approach that adheres to specified processes as the system moves through a series of representations from requirements through design to finished product.
- C. Systems engineering is an iterative process of top-down synthesis, development, and operation of a real-world system that satisfies, in a near optimal manner, the full range of requirements for the system.
- D. Systems engineering is an interdisciplinary approach and means to enable the realization of successful solutions.
### Review Layout (as I recall)

#### Review Marked Questions

<table>
<thead>
<tr>
<th>Question #</th>
<th>Incomplete</th>
<th>Marked</th>
<th>Complete</th>
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<tbody>
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<td>Question 1</td>
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<tr>
<td>Question 2</td>
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<td>Question 3</td>
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<td>X</td>
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<tr>
<td>Question 4</td>
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<td>Question 5</td>
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<td>Question 6</td>
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<td>Question 7</td>
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<td>Question 8</td>
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<td>Question 9</td>
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<tr>
<td>Question 10</td>
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</tbody>
</table>

#### Review Incomplete Questions

- Click on question to return to it (This shows previous screen)
- Go to ‘Finish: Yes/ No’ screen. Once you click ‘Yes’ you will get your result within roughly a minute

#### Finish

- Marked Questions
- Incomplete Questions

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FAQs

• Distribution of questions
• Pass Rate/Percentage
• Exam Feedback

• Proficient
• Marginal
• Deficient

<table>
<thead>
<tr>
<th>INCOSE CSEP/ASEP Exam Top-Level Learning Objective Categories</th>
<th>Primary Mapping to the INCOSE SE Handbook</th>
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<tbody>
<tr>
<td>General Systems Engineering Knowledge</td>
<td>Chapters 1-3</td>
</tr>
<tr>
<td>Systems Engineering Technical Processes</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>Systems Engineering Technical Management Processes</td>
<td>Chapter 5</td>
</tr>
<tr>
<td>Systems Engineering Organizational/Enterprise and Agreement Processes</td>
<td>Chapters 6-8</td>
</tr>
<tr>
<td>Specialty Engineering Activities</td>
<td>Chapter 9</td>
</tr>
</tbody>
</table>
A brief overview of the handbook structure and content
SEH History

Internal Draft 1994 by approximately 47 volunteers

Version 1.0: Jan 1998 (279 pages, 322 including appendixes)
- Released under INCOSE name during the interim review of EIA/IS 638 and IEEE 1220-1994
- Objective: Description of the key process activities performed by Systems Engineers
- Intended as a resource for young Systems Engineers, Engineers from other disciplines and as a reference

Version 2: Early 2002
- Changes to conform to ANSI/EIA-632 and EIA-731, new contributions
SEH History

**Version 2a: June 2004** (187 pages, 320 including appendixes)
- SE Certification Handbook (Shorten main body)
- Less DoD Centric
- Rebalancing degrees of topic depth
- Restructuring for readability
- Grammatical fixes

**Version 3: June 2006** (171 pages, 185 including appendices)
- Aim to evolve appendices on significant issues that are available online
SEH History

- **Version 3.1: Aug 2007** (174 pages, 304 including appendices)
- Stand alone reference fully supporting CSEP
- 15 appendices added
- Some issues:
  - Some topics addressed as much as 5 times
  - Inconsistent usage of terminology
  - Poor organization and much duplication
  - Conflicting content
SEH History

Version 3.2 January 2010 (344 pages, 374 including appendices)

- Alignment with the latest 2008 version of ISO/IEC 15288 international standard
- Resolves inconsistencies in Version 3.1, primarily in the areas of terminology, figure-to-figure & figure-to-text consistency
- Consolidates related process information throughout the text to remove the multiple treatment of topics
- Minimizes impact to the INCOSE CSEP/ASEP certification exam
- Single Reference. INCOSE Body of knowledge
Overview

1. SE Overview
2. Generic Life Cycle Stages
3. Processes →
4. Tailoring
5. Speciality Engineering Activities

Figure 1-1 System Life-cycle Processes Overview per ISO/IEC 15288:2008
Example: System of Systems (SoS)

Transport SoS
Multiple systems of interest depending on view

Camera SoS
Complexity due to multiple variants
Example: Use of Systems Engineering

When 20% of the actual cost has been accrued, 80% of the total LCC has already been determined.
Example: Life Cycle Stages

• The purpose in defining the system life cycle is to establish a framework for meeting the stakeholders’ needs in an orderly and efficient manner.

• This is usually done by defining life cycle stages and using decision gates to determine readiness to move from one stage to the next.

• Skipping stages and eliminating “time consuming” decision gates can greatly increase the risks (cost and schedule).

• Systems Engineering usually concentrates on the early stages but both commercial and government organizations recognize the need for SE throughout the life span.

• The role of the systems engineer encompasses entire life cycle.
Example: Three Life Cycle Aspects

- Business (Business Case)
- Budget (Funding)
- Technical (Product)
Example: Decision Gates

Decision gates, also known as control gates, are often called “Milestones” or “Reviews”

Questions:

• Satisfy Business Case?

• Affordable?

• Can be delivered when needed?
Example: Vee Model

Figure 3-4 Vee model

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Example: Life Cycle Approaches

• Plan Driven Development
• Incremental and Iterative Development
• Lean Development
• Agile Development
Example: LSE: Principles

Figure 3-9 Lean Development Principles
Example: Process Overview

What Does An Agile Process Look Like?

- **Product Owner**
- **Team Leader**
- **Iteration Tasks**
- **Agile Team**
- **Executable Product Increment**
- **Prioritized & Estimated Features**
- **Iteration Planning**
- **Feedback & Refinement**
- **Iteration Review**

Requirements & Business Conditions

7/4/2005

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Certification Training International Pty Ltd 2014
Case Study: Therac-25
Case Study: Øresund Bridge
Case Study: Shanghai's Transrapid Maglev Line
Technical Processes

Figure 1-1 System Life-cycle Processes Overview per ISO/IEC 15288:2008
Example: Stakeholder Requirement Definition Process

**Purpose:** Define the requirements for a system that can provide the services needed by stakeholders in a defined environment

- (A stakeholder is any entity (individual or organization) with a legitimate interest in the system)
- **Purpose?**
- **Inputs?**
- **Outputs?**
- **Activities?**
- **Enablers and Controls?**
- **Approaches & Tips?**
- **Position in life cycle?**

![Diagram](image-url)
Example: Stakeholder Requirement Definition Elaboration

- **AIM**: Understand the needs of the stakeholders well enough to support the Architectural Design Process
- Depending on model, Stakeholder Requirements Captured once near development cycle beginning or continuous
- **Stakeholder identification one of biggest challenges** (Any entity (individual, organization, inter-operating or enabling systems, future generations) with a legitimate interest in the system)

**Steps**
1. ID Users and Stakeholders
2. Define Needs
3. Capture Source Requirements
4. Initiate Requirements Database
5. Establish Concept of Operations (ConOps)
6. Generate Systems Requirements Document
Example: (2) Defining Needs

1. Identify users and other stakeholders & understand their needs. Use surveys
2. Perform mission analysis to establish the environment, requirements, and architecture
3. Document the inadequacies or cost of existing systems to perform new mission needs
4. If mission success is technology driven, develop concepts and new capabilities made possible
5. Justify the need for this mission compared to alternative missions competing for the same resources
6. Prepare the necessary documents to request funding for the first programme stage
7. If procurement is involved, develop RFP, establish selection criteria and perform source selection
Example: (2) Defining Needs (2)

Contributing users rely on well defined completion criteria to indicate successful definition of needs:

- User organizations have gained authorization for new system acquisition
- Program development organizations have
  - **SOW**
  - **SRD**
  - Gained approval for new system acquisition
  - If intending to use outside support RFP and selected a contractor

- Potential contractors have influenced the acquisition needs, submitted a proposal, and have been selected to develop and deliver the system
- If market driven, the marketing group has learned what consumers want to buy. For expensive items (e.g. aircraft) they have obtained orders for the new systems
- If market and technology driven, the development team has obtained approval to develop the new system from the corporation
Example: (3) Capture Source Requirements

Techniques: Interviews, Focus Groups, Delphi technique, Soft Systems Methodology

Examples of typical inputs:

1. New or updated customer needs, requirements, and objectives in terms of missions, ConOps, MOE’s, technical performance, utilization environments, and constraints

2. Technology base data including identification of key technologies, performance, maturity, cost, and risks

3. Requirements from contractually cited documents for the system and its configuration items (CI’s)

4. Technical objectives

5. Records of meetings and conversations with the customer
Example: (4) Initialize the Requirements Database

**Objective:** Establish a database of baseline system requirements traceable to the source needs and requirements, foundation for later refinement and/or revision by subsequent SE Process activities

<table>
<thead>
<tr>
<th>Prerequisites for Success</th>
<th>Minimum Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Empower systems analysis team</td>
<td>1. Project requirements</td>
</tr>
<tr>
<td>2. Experienced Lead Systems Engineer(s)</td>
<td>2. Mission requirements</td>
</tr>
<tr>
<td>3. Experienced team members from relevant disciplines</td>
<td>3. Customer specified constraints</td>
</tr>
<tr>
<td>4. Formal decision mechanism and any supporting tools</td>
<td>4. Interface, environmental, and non-functional requirements</td>
</tr>
<tr>
<td>5. Relevant training on selected tools</td>
<td>5. Issues discovered</td>
</tr>
<tr>
<td>6. Define the formats of the output</td>
<td>6. An audit trail of issues resolution</td>
</tr>
<tr>
<td></td>
<td>7. V&amp;V methods required</td>
</tr>
<tr>
<td></td>
<td>8. Traceability to source</td>
</tr>
<tr>
<td></td>
<td>9. Substantiation that the database is a valid interpretation of user needs</td>
</tr>
</tbody>
</table>
### Example: (5) Establish ConOps

<table>
<thead>
<tr>
<th>Scenario building is an essential tool for planning and decision-making in complex and uncertain environments</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Stakeholder Requirements Definition Process suggests concept documents each focused on a specific life cycle stage:</td>
</tr>
<tr>
<td>- Concept of Production</td>
</tr>
<tr>
<td>- Concept of Deployment</td>
</tr>
<tr>
<td>- ConOps</td>
</tr>
<tr>
<td>- Concept of Support</td>
</tr>
<tr>
<td>- Concept of Disposal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The primary goal is to capture, early in the system life cycle, an implementation-free understanding of stakeholders’ needs by defining what is needed, without how</th>
</tr>
</thead>
<tbody>
<tr>
<td>It captures behavioral characteristics required of the system in the context of other systems with which it interfaces, and captures the manner in which people will interact with the system for which the system must provide capabilities</td>
</tr>
</tbody>
</table>
Example: (5) Establish ConOps (2)

**Primary objective:** Early communication with the end user to ensure that operational needs and the rationale for performance requirements are clearly understood and incorporated

**Other Objectives:**

1. Traceability between operational needs and captured requirements
2. Establish a basis for requirements for systems support over its life
3. Establish a basis for verification planning, system-level verification requirements, and any requirements for environmental simulators
4. Generate operational models to test the validity of external interfaces
5. Basis for calculating system capacity, under/overload behavior, and mission-effectiveness
6. Validate requirements at all levels and to discover implicit requirements overlooked from other sources
Example: (5) Establish ConOps (3)

A ConOps document is established as follows:

1. From source operational requirements deduce and record the statements describing the system objectives
2. Review with end users and operational personnel, record the conflicts
3. Define and model operational boundaries
4. Generate a context diagram to represent the model boundary
5. Identify possible I/O events between the system and external systems
6. Add functions to the context diagram to represent significant transformations due to I/O events (I/O events in DB for timing)
7. Record System Interfaces
8. For each interaction class create a functional flow diagram to model the interaction sequence triggered by stimuli from the external systems
9. Add information to trace the function timing from performance requirements, simulate the timing of the functional flow diagrams to confirm operational correctness, review with users and ops. personnel
10. Develop user approved timelines to supplement source requirements
Example: (6) Generate SRD

- Generate a draft System Requirements Document if one does not already exist
- This is the highest level document to be created by the project
- If an SRD already exists, it should be reviewed internally and with the customer to ensure that it is valid, meets the customer needs, and is clearly understood by all stakeholders
Example: Quality Function Deployment (QFD): The House of Quality

- Useful technique, particularly where the “voice of the customer” is not clear
  - The shaded Relationship Matrix shows the correlation between features and requirements
  - Double Circle = strong correlation
  - Circle = modest contribution
  - Blank column = unnecessary feature relative to the listed requirements
  - Blank row = unaddressed requirement

- Other useful methods: functional decomposition, using a system hierarchy, FFBD’s, time lines, control/data flow diagrams, trade studies, and requirements allocation sheets
Example: Cross Cutting Technical Methods
Example: Modeling, Simulation, and Prototyping

- Models and Simulation Key Benefits:
  - Confirms anticipated system behaviors before proceeding with actual development
  - Presents a clear, coherent design to those who will develop, test, deploy, and evolve the system, maximizing productivity and minimizing error
- Model: Represents the essential characteristics of the system, environment, interactions, (Input to Output) often via logical or mathematical rules
- The result of modeling is a prediction of characteristics across the spectrum of system attributes throughout its life cycle
- Two types of models are particularly important to SE:
  - Descriptive models clarify the context, content, structure, and behavior of the problem; identify what stakeholders are willing to do about the problem; and describe the relevant characteristics of appropriate technologies
  - Prescriptive models specify the intended system in terms of its necessary and sufficient capabilities, the order of all relevant technologies and components, and the emergent characteristics expected of the system throughout operational situations, modes, and phases. Prescriptive models also contain or generate an estimate of the likelihood that an envisioned system will meet its MOE’s
Example: Functions-Based Systems Engineering Method: Process Activities

At each level of the process, alternative decompositions and allocations may be considered and evaluated for each function and a single version selected. After all of the functions have been identified, then all the internal and external interfaces to the decomposed sub-functions are established.
Example: The OOSEM

- **Causal analysis**
- **Enterprise model**
- **Elaborated context**
- **Requirements variation analysis**
- **System/logical decomposition**
- **Partitioning criteria**
- **Node allocation**
  - **Top down SE approach**
  - **Recursive SE process**
  - **Use case/scenario driven (req'ts – test)**
  - **Black box/white box**
  - **OO concepts**
  - **UML/SysML**
  - **SE Process**
  - **Reqs, Trados, …**

---

**Major SE Development Activities**

1. **Analyze Needs**
   - • Causal analysis
   - • Mission use cases/scenarios
   - • Enterprise model

2. **Define System Requirements**
   - • System use cases/scenarios
   - • Elaborated context
   - • Req't's diagram

3. **Define Logical Architecture**
   - • Logical decomposition
   - • Logical scenarios
   - • Logical subsystems

4. **Synthesize Allocated Architecture**
   - • Node diagram
   - • HW, SW, Data arch
   - • System deployment

5. **Optimize & Evaluate Alternative**
   - • Parametric Diagram
   - • Trade study

6. **Validate & Verify System**
   - • Test system
   - • Test cases

**Common Subactivities**
Project Processes

Figure 1-1 System Life-cycle Processes Overview per ISO/IEC 15288:2008
Example: IPPD Overview

• Evolved from recognizing the need to consider all elements of the product life cycle, from conception through disposal, starting at the beginning of the life cycle

• Productivity Gains from:
  • Unleashing the team’s ingenuity through decentralized processes
  • Avoidance of previous problems through new, creative approaches
  • Better integration between engineering and manufacturing

Note the definitions in this section!

• Objective of IPPD:
  • Reduce time to market
  • Improve product quality
  • Reduce waste
  • Save costs through the complete integration of SE life-cycle processes

• Additional Benefits of IPPD:
  • Improves team communications through IPDT’s
  • Implements a proactive risk process
  • Makes decisions based on timely input from the IPDT
  • Improves customer involvement
### Example: Steps to Organize & Run a High-Performance IPDT

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>Define the IPDT teams:</strong> Develop IPDT teams that cover all project areas</td>
</tr>
<tr>
<td>2.</td>
<td>Delegate <strong>responsibility and authority</strong> to experienced IPDT Leaders</td>
</tr>
<tr>
<td>3.</td>
<td><strong>Staff the IPDT</strong> with the correct candidates</td>
</tr>
<tr>
<td>4.</td>
<td>Understand the team’s <strong>operating environment</strong></td>
</tr>
<tr>
<td>5.</td>
<td>Plan and conduct the <strong>Kick-Off Meeting(s)</strong> (two recommended)</td>
</tr>
<tr>
<td>6.</td>
<td><strong>Train</strong> the team for their role</td>
</tr>
<tr>
<td>7.</td>
<td>Define the team <strong>vision and objectives</strong></td>
</tr>
<tr>
<td>8.</td>
<td>Have each team <strong>expand its job definition</strong> (tasks, roles, responsibilities, and milestones)</td>
</tr>
<tr>
<td>9.</td>
<td>Establish a <strong>Process Assessment and Continuous Improvement routine</strong></td>
</tr>
<tr>
<td>10.</td>
<td><strong>Monitor</strong> team <strong>progress</strong> via measures and reports</td>
</tr>
<tr>
<td>11.</td>
<td><strong>Sustain and evolve</strong> the team throughout the project</td>
</tr>
<tr>
<td>12.</td>
<td><strong>Document</strong> team products</td>
</tr>
<tr>
<td>13.</td>
<td><strong>Close the project and conduct follow-up activities</strong></td>
</tr>
</tbody>
</table>
Example: Key Trade Study Activities (3)

Prepare Formal Trade Study Reports

1. **State the scope** of the report
2. **Trade Study Team:** names, roles and any specialties
3. **Functional and performance design requirements:** functional requirement, related performance requirements, reference source
4. List of possible design approaches and significant characteristics and risks of each. List rejected alternatives with brief justification
5. **Characteristic comparison matrix** for each design approach showing the degree of satisfaction for rapid comparison
6. **Recommended design approach** with substantiation including necessary documentation

Unique identification number for each trade study report if multiple trade studies are prepared

<table>
<thead>
<tr>
<th>Feature or Design Requirement</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
<th>Alternative 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements 1 (Weight)</td>
<td></td>
<td></td>
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<tr>
<td>Requirements 2 (Weight)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirements n (Weight)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. **Design Approach Recommended**
   A. 
   B. 
   C.
Example: Risk Management Concepts

- Risk has **2 components**: Likelihood of occurrence and consequence if the event occurs (can be both positive or negative)
- Risk is always present. The **challenge** is to define the system and the project that best meet overall requirements, allow for risk, and achieve the highest chances of project success

![Risk Management Concepts Diagram](image-url)
Agreement Processes

Figure 1-1 System Life-cycle Processes Overview per ISO/IEC 15288:2008
Organizational Project-Enabling Processes

Figure 1-1 System Life-cycle Processes Overview per ISO/IEC 15288:2008
Example: Project Portfolio Management Process

**Purpose:** To initiate and sustain necessary, sufficient and suitable projects in order to meet the strategic objectives of the organization

- **Purpose?**
- **Inputs? Outputs?**
- **Activities?**
- **Enablers and Controls?**
- **Approaches & Tips?**
- **Position in life cycle?**
Example: Define Business Case & Develop Business Area Plans

• The Business Case and associated Business Area Plans establish the scope of required resources and schedule, and set reasonable expectations.

• At each design gate: Realistically review business case.

• Result is re-verification or restatement of business case.

• Variety of ways to validate business case:
  • Sophisticated engineering model (large projects)
  • Prototypes of key system elements (large projects)
  • Demonstration at 20% of development costs (complex systems)
  • Proof-of-concept models during the Concept Stage (smaller projects)

• Opportunities evaluated against the portfolio of existing agreements and ongoing projects, and attainability of stakeholders’ requirements.
Example: Tailoring Process

Figure 8-1 Tailoring requires balance between risk and process.
Example: Specialty Engineering Activities

- Consult and involve subject matter experts as appropriate
- Topics covered (alphabetical order):
  - Design for Acquisition Logistics (Integrated Logistics Support)
  - Cost-Effectiveness Analysis
  - Electromagnetic Compatibility Analysis
  - Environmental Impact Analysis
  - Interoperability Analysis
  - Life Cycle Cost Analysis
  - Manufacturing and Producibility Analysis
  - Mass Properties Engineering Analysis
  - Safety & Health Hazard Analysis
  - Sustainment Engineering Analysis
  - Training Needs Analysis
  - Usability Analysis (Human Systems Integration)
  - Value Engineering
Examples of Questions
Q: Which of the following are valid definitions for Systems Engineering? (Choose 3)

A. Systems Engineering is a discipline that concentrates on the design and application of the whole (system) as distinct from the parts

B. Systems Engineering is characterized by a systematic approach that adheres to specified processes as the system moves through a series of representations from requirements through design to finished product

C. Systems Engineering is an iterative process of top-down synthesis, development, and operation of a real-world system that satisfies, in a near optimal manner, the full range of requirements for the system

D. Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems
Q: Which of the following are challenges related to the development of a System of Systems (SoS)? (Choose three)

- A. System elements have different life cycles
- B. Engineering complexity can overshadow management
- C. System of System (SoS) engineering is never finished
- D. Complexity is a major issue
- E. Different systems exists at different levels

SEH: 2.5
Question 3

Q: Select the valid Lean Development Principles (choose three)

☑ A. Value
☑ D. Value Stream
☑ E. Respect for People
☐ B. Balance
☐ C. Waste Elimination

SEH: 3.4.3.3.
Question 4

Q: The purpose of the Stakeholder Requirements Definition Process is to …? (choose one)

- A. ...elicit the total set of requirements from all involved stakeholders
- B. ...transform the stakeholder, requirement-driven view of desired services into a technical view of a required product that could deliver those services
- C. ...define the requirements for a system that can provide the services needed by users and other stakeholders in a defined environment
- D. ...define what the system must accomplish and how well

SEH: 4.1.1.1.
Question 5

Q: Which of the following is not an output of the architectural design process?: (choose one)

- A. Technical Performance Measure (TPM) Data
- B. System Architecture
- C. System Element Descriptions
- D. Validation Criteria

SEH: 4.3.1.4.
Q: Which of the following would be most valuable in the definition of a Concept of Operations (ConOps)? (choose three)

- A. Measure of Performance and Effectiveness (MPE) Analysis
- B. Functional flow block diagrams (FFBD)
- C. Product Breakdown Structure Diagrams
- D. Time-line charts
- E. Interface Working Group (IFWG) meetings

SEH: 4.1.2.5.
Q: Which of the following techniques is useful in particular where the "voice of the customer" is not clear? (choose one)

- A. Kepner-Tregoe Analysis (KTA)
- B. Model-Based Systems Engineering (MBSE)
- C. Quality Function Deployment (QFD)
- D. Value Analysis (VA)

SEH: 4.2.2.4.
Q: What are the three important benefits of Life Cycle Cost (LCC) Analysis? (choose three)

- A. Project managers can develop accurate revenue predictions
- B. All costs associated with a system become visible
- C. It forces the development of a definitive cost proposal for the programme
- D. Supports an analysis of organization interrelationships
- E. It results in cost savings over the life of the programme

Ref: 9.6.
Q: Which Integrated Product Development Team (IPDT) would typically focus on Deliverable Item Issues & Integrity? (choose one)

- A. The System Engineering and Integration Team (SEIT)
- B. The Product Integration Teams (PIT’s)
- C. The Product Development Teams (PDT’s)
- D. None of the above

SEH: 5.1.2.3..
Q: What is the purpose of the Project Portfolio Management Process?: (choose one)

- A. To analyze and collectively managing a group of current or proposed projects based on numerous key characteristics
- B. To initiate and sustain necessary, sufficient and suitable projects in order to meet the strategic objectives of the organization
- C. To plan, organize, secure and managing a group of resources to successfully complete a portfolio of projects
- D. None of the above

SEH: 7.3.1.1.
Questions

Francois Retief: francois@iono.fm