GALORATH

# Estimating System Level Cost

**PSM Conference**
**Keystone, CO**
**2004**

**Evin Stump**



GALORATH

## Issues

- **Are there significant "system level" costs beyond building and integrating subsystems?**
  - Yes, according to NASA and others
- **Do most cost models adequately capture these costs?**
  - No, according to NASA and others
- **How important is it to estimate these costs?**
  - Very—they can be as large as 100% or more of the sum of all subsystem level costs
  - In the past, NASA and others have typically estimated them by using "factors" on top of all other costs
- **What exactly are system level costs, and what do they pay for?**
  - What they are is not the easiest question to answer—lots of ambiguity—depends on how you define a "system"
  - What they pay for—the assurance that the total "system" performs as intended

## Another Issue

- **Is there such a thing as system level cost for software only?**
  - All software "systems" eventually involve hardware at some point
  - BUT…the complexity and integration problems of modern software systems can become huge while the related hardware costs are still minimal



## How We Are Responding

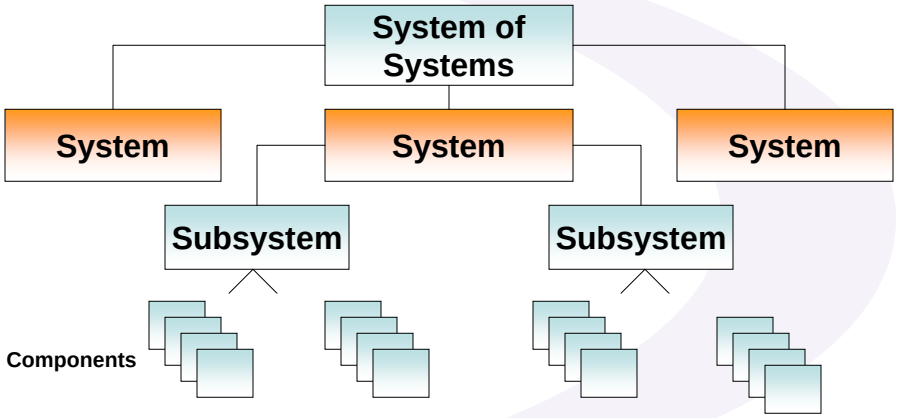
- **SLC: An initiative to incorporate system level costs into Galorath's SEER-H (hardware) cost model**
  - Software costs are separately estimated in SEER-SEM and linked to SEER-H for inclusion in the system
  - System level costs are estimated based on the combined costs and complexity of hardware and software
- **Purpose: to allow estimators to include both subsystem and system level costs in a single estimate**
- **Initial data research effort funded by NASA IPAO**
- **Main source of data: NAFCOM (NASA/USAF) 2002 database**
- **Other sources: Industry survey, in-house data and expert opinion**

**SLC will become a regular feature of SEER-H with the release of version 6.0, fall of 2004.**

GALORATH

# System Level Cost (SLC)

- What is system level? One way of defining is by a hierarchy
- But this is subject to misinterpretation—one engineer's system can be another engineer's subsystem

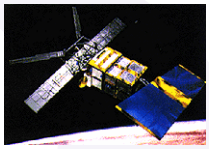





GALORATH

# Another View (Common in Aerospace)

- **System:** Combination of several subsystems, sets, etc. which work together to perform one or more operational functions. Some of the components of a system may be physically separated.
- There seems to be a consensus that the following are all true:
  - A system typically includes the support equipment that "touches" it
  - It typically does not include the infrastructure that "supports" it
  - Multiple systems can operate cooperatively to form a system of systems that performs a "mission"
  - Examples of cooperating systems:
    - Launch vehicle (system)
    - Spacecraft (system)
    - Ground station (system)



## A High Level View

- **Subsystem costs (costs below system level) cover answering the question "Are each of the subsystems correctly configured according to plan and do they work as designed?"**

**Includes answering the question "Do each of the subsystems work as designed with respect to the other subsystems with which they interact?"**

- **System level costs (costs at system level) cover answering the question "Is the entire system configured according to plan and does it work as designed?"**

**Includes answering the question "Does the system work as designed with respect to cooperating systems and to its mission?"**



## When Is It Appropriate to Add SLC?

- **Requires judgment on the part of the cost analyst**
  - **Any collection of hardware (and software) that is assigned a well-defined subset of a larger *mission* (human purpose) is generally a system**
    - Mission: Lift a manned vehicle into space (system=Saturn V launch vehicle)
    - Mission: Carry astronauts from earth to lunar orbit and back (system=Apollo command module)
    - Mission: Carry astronauts from lunar orbit to moon's surface and back (system=lunar lander)
    - Mission: Allow astronauts to drive around on the lunar surface (system=lunar rover)
  - **Any collection of hardware and/or software that merely contributes to the functioning of a larger collection of hardware is generally NOT a system, especially if it is a purchased part or installation**
    - Engine in a ship (for a prime contractor, but for the sub who builds it, it could be a system)
    - Cockpit controls in an aircraft
    - Attitude control in a spacecraft

## Other Criteria to Consider

- **A collection of hardware and/or software flowing into an integrating contractor from various subcontractors and emerging as a completed product is probably a system**
- **If "systems engineers" are involved in making it all come together, it's probably a system**
- **If it has a distinct management component it may be a system**
- **If it includes dedicated support equipment it may be a system**
- **A system can "use" another system to achieve part of its functionality, but it generally should be able to operate more or less independently at least part of the time**
- **If the estimated costs of building and integrating the subsystems seems to missing something, it's probably a system**



## Treatment in SEER-H

- **Work elements in SEER-H are of the following types:**
  - Mechanical/Structural
  - Electronic
  - Site
  - Add-in
  - **Rollup**
- **Of these, only a rollup can be at system level**
- **But…a rollup is not automatically at system level**
  - Assignment of a rollup as "system level" is a decision of the SEER-H user
  - It requires user judgment

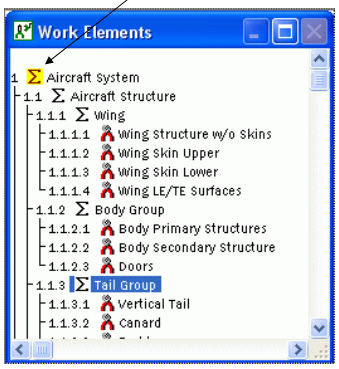
## The SLC Work Element , Subsystem, System Taxonomy

- **Individual work elements may be components, units, subassemblies, or even assemblies, depending on point of view. We group all these simply as "work elements" to minimize possible confusion**
- **In SEER-H, an individual work element and all other individual work elements *and external entities* with which it is "integrated" in any sense comprise a "subsystem" focused on that work element**
  - Integration includes attachment, calibration, cooperation, energizing, influencing, signaling, support, installation, adaptation, etc.
  - A work element may be member of more than one subsystem and must belong to at least one (the one of which it is the focus)
- **A set of work elements under a system level rollup is by definition a system—elements or external entities with which any system element forms a subsystem are *not necessarily* part of the same system**
- **A work element not intended to be a part of a system *must not* be listed in any WBS branch under the SLC rollup**
- **A work element intended to be a part of a system must be listed in some branch under the system level rollup**



## Where You Can Make a System Level Cost Assignment

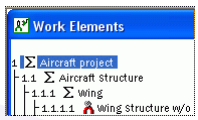
**Yellow shading of the sigma symbol indicates a system level assignment at a rollup.**



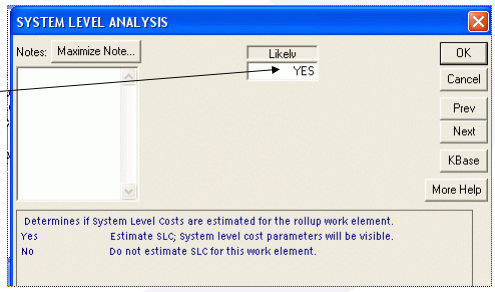

- **Assignment of a rollup work element as system level can be done at any time after the work element is created**
  - These assignments can be reversed at any time
  - The assignment can be made at the top rollup or at any junior rollup, as appropriate
- **More than one system level assignment can be made in a given work element structure—in fact, every rollup can potentially be made a system level cost element**
  - That is not the same as saying that it's appropriate to do so

# Creating System Level Costs

- **SLCs can be created at any rollup work element**
  - First, select the rollup element where you want to create SLCs
  - Next, in parameter view select System Level Analysis
  - Then, double click to open the System Level Analysis window. Change NO to YES and close the screen.



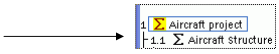


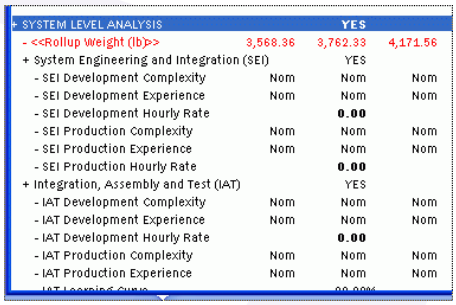





# What This Does

- **This does two things**
  - The sigma symbol for the selected work element will be shaded yellow
  - A new list of parameters will be opened in parameter view
- **These parameters control the amount of SLC that will be generated**
  - SLC can be generated for either or both development and production phases
  - The amount of SLC generated is a function of the existing costs below system level and user settings for Experience and Complexity



## A Caution!!

- **Be careful about creating one or more SLC rollups below another SLC rollup**
- **This implies a system of systems**
- **It could be valid to do this if you have prior data or experience which you can use to test and calibrate the results if necessary**
- **Most of the data underlying the present SLC feature is from systems, not systems of systems**
  - However, the small amount of data that does represent systems of systems appears to be statistically similar to the systems data
- **Some systems of systems can involve great complexities that are at present on the edge of the state-of-the-art of parametric tools**
- **We are working to validate that the SLC feature reasonably represents systems of systems**

**This is a subject of increasing importance as modern systems grow in size and complexity.**



## About the Complexity and Experience Parameters

- **Aside from labor rates and subsystem level costs, the Complexity and Experience parameters drive the various SLCs**
- **These parameters work in opposite directions—increasing Complexity increases cost, while increasing Experience decreases it; the reverse is also true**
- **Both Experience and Complexity are on a conventional SEER 14 point scale ranging from Vlo- to Vhi. Both parameters make available the usual SEER three point settings: Least, Likely, Most**
  - These generate cost risk the same way as the three point settings for other SEER parameters
  - They do not generate schedule risk because the SLC feature does not generate project duration information
  - Development duration risk at a rollup is still generated only by the risk settings for the electronic, mechanical, and addin elements

## Nature & Components of SLC

- **System Level Cost takes a "god's eye" view of integration (top down)**
- **Up to five distinct system level cost increments can be estimated (or omitted if deemed inappropriate) in development:**
  - System program management (SPM)
  - System engineering and integration (SEI)
  - System test operations (STO)
  - System integration, assembly and test (IAT)
  - System support equipment (SSE)
- **Up to three distinct system level cost increments can be estimated (or omitted if deemed inappropriate) in production:**
  - System program management (SPM)
  - System engineering and integration (SEI)
  - System integration, assembly and test (IAT)



## Definitions of SLC Components

- **The definitions on subsequent charts closely resemble definitions used by NASA and USAF**
- **NASA also regards launch and orbital operations support as a system level cost for space systems, but we did not include it because 1) most systems are not space systems, and 2) we regard it as an operational cost, not an acquisition cost.**

## Definition of SEI

- **System Engineering and Integration in development and in production includes at the system level:**
  - Translation of operational needs into system requirements
  - Specification of system configurations that can meet the needs
  - System optimization
  - Planning, monitoring, measuring and directing the overall technical program, including:
    - Cost/performance tradeoffs
    - Support of engineering changes
    - Selection of technologies
    - Safety, reliability and quality assurance engineering
    - Logistics engineering
    - Creation and maintenance of interface control documents
- **Excluded are all of the above functions at the subsystem level**



## Definition of IAT

- **Integration, Assembly & Test in development at the system level includes labor and material for integration, assembly and test of major test articles**
- **Integration, Assembly & Test in production at the system level includes:**
  - Labor and material required to accomplish final assembly of all subsystems into a complete system
  - Design and manufacture of installation hardware
  - Final factory acceptance operations
  - Packaging, crating and shipping operations
- **Excluded is engineering effort related to IAT, which is covered under SEI, and all of the above functions at the subsystem level**

## Definition of SPM

- **System Program Management in development and production includes:**
  - Effort required for management direction and decision making to ensure that a product is developed, produced and delivered
  - Includes direct charges for program administration and the management of all functions associated with engineering, manufacturing, support, quality assurance, configuration and project control, and documentation
- **Excluded are all of the above functions at the subsystem level**



## Definition of STO

- **System Test Operations includes:**
  - At system level, all test planning and scheduling, testing, and data reduction and reporting for development testing, qualification testing, and any testing to determine the compatibility with the overall system and its intended operational parameters
  - This includes operational tests, design verification tests and reliability tests
  - It also includes testing to verify acceptability for required mission performance
  - These tests are performed on hardware that has been produced, inspected, and assembled in accordance with final design requirements
  - Included are design and fabrication of test fixtures needed for the tests
- **Excluded are all of the above functions at the subsystem level**

GALORATH

# Definition of SSE

- **System Support Equipment includes:**
  - Labor and material required to design, develop, manufacture, procure, assemble, test, and deliver equipment necessary for system level final assembly and test
  - Equipment utilized for integrated and/or electrical checkout, handling, protection, transportation, and calibration, and items such as conversion kits, work stands, equipment racks, trailers, fueling, cryogenic and gas supply equipment, and miscellaneous equipment of all types.
- **Excluded are all of the above at the subsystem level**



GALORATH

**For more information:**
**www.galorath.com**
**Tel: 951-676-7804**
**E-mail: estump@galorath.com**