General information at
www.espcomposites.com

Course homepage
courses.espcomposites.com

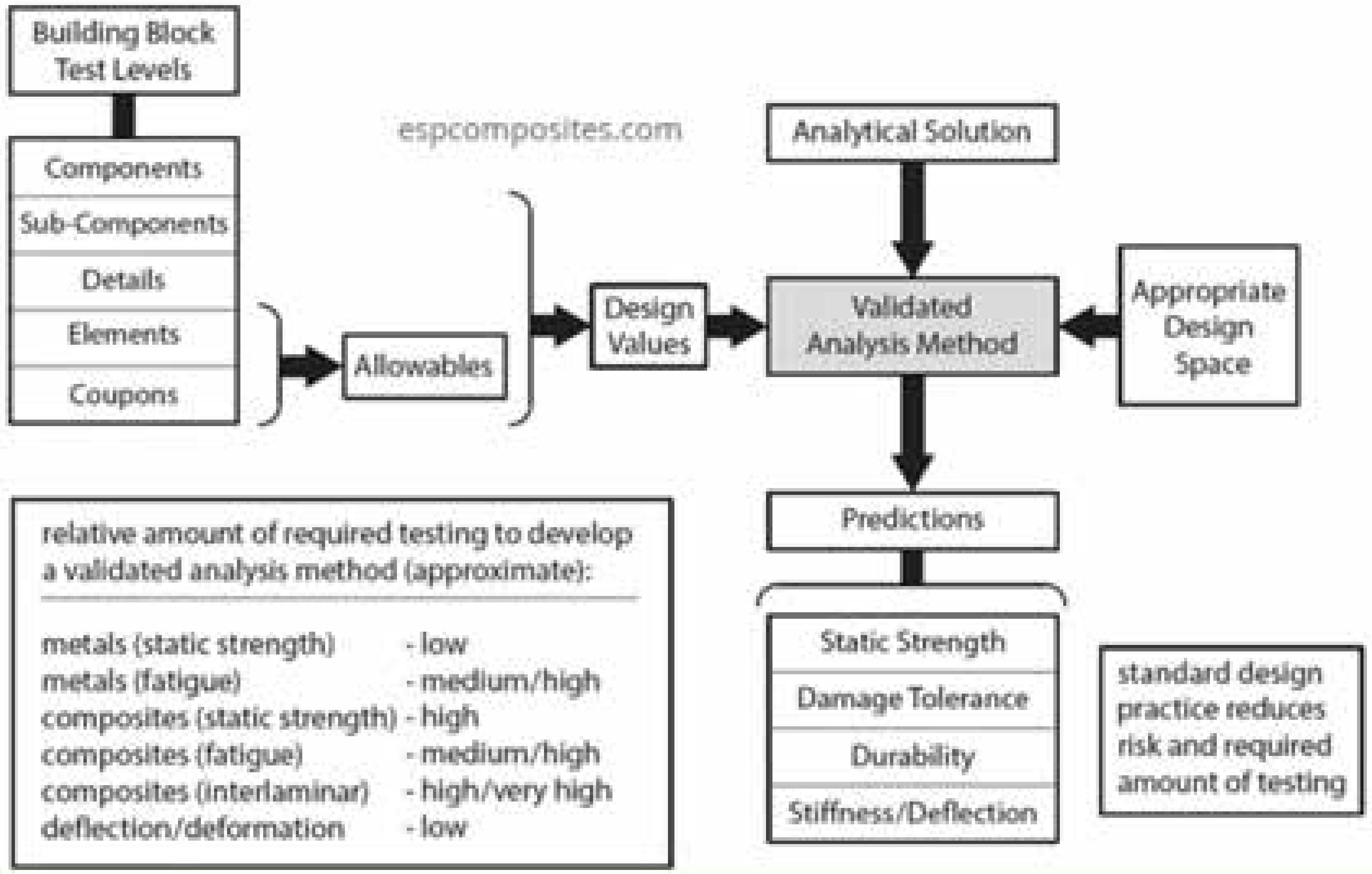
Special Topic 1: Developing a Validated Analysis Method

ST1.1 — Overview

- Audience: those taking the course or who have the book
  - may also be relevant to those familiar with composites
- **Offered as a Free video/PDF and part of the course**
  - contains some additional information not in the book
  - assist engineers with an industry analysis option ("non-academic" approach)
- Goal
  - Introduce the fundamental principles in which to develop a validated analysis method

ST1.1 — Overview (cont.)

- Validated analysis method
  - presented in Chapter 2
  - an **engineering** analysis approach, *especially effective for problems that are not well-suited to classical solutions*
    - **strength prediction for composites** is a prime example (especially when interlaminar stresses play a significant role)



ST1.1 — Overview (cont.)

- This special topic presents **one way** to develop a validated analysis method
  - ***no absolute black and white process***
- Demonstrate the **basic principles** and **general exposure** to the concept. The **specific approach** may be more detailed and is a function of many factors such as:
  - small versus large aircraft
  - civil versus military aircraft
  - critical versus non-critical structures
  - resources
  - other factors
- This special topic is an additional resource and compliments the course and the book (not a direct chapter or section of the book)
  - however, aspects are discussed in the book

ST1.2 — Analysis Problem Categories

Consider **two broad categories** for analysis problems

- **First Category:** Problems well-suited to classical solutions ("hand calculation solutions" consistent with academic theory)
  - relatively predictable with classical solutions alone
    - or accurately predicted with numerical methods or straightforward finite element analysis (FEA)
  - minimal amount of testing required to validate the analytical solution
  - can be implemented in a practical manner (not overly complex – can be completed with the given resources, time, and cost)
  - Examples: many metal problems (deflection **and** static ultimate strength)
  - Examples: stiffness/deflection of composite structures
  - first category problems are usually the **well-accepted analysis solutions** within the industry

ST1.2 — Analysis Problem Categories

- **Second Category:** Problems **not well-suited to "pure" solutions**
  - problems where the actual physical behavior is not captured with classical solutions or "hand calculations".
  - problems where an increase in analysis fidelity (such as numerical methods or nonlinear FEA) can not address the physical limitations of the problem.
    - general strength prediction of composites is a prime example (Chapters 8, 9, 10, ST2)
  - problems where the physics may be captured, but the analytical complexity prevents it from being practical
  - when developing a validated analysis method, the result is likely to be **unique** (specific to the **blend** of analysis and testing used)
    - however, there are industry trends for some types of problems
  - general strength prediction of composites (especially open holes, mechanically fastened joints, post-impact strength, problems where interlaminar stresses play a role, etc)
  - composites tend to have more problems in this category than metals do

***For a given analysis problem**: Usually requires industry knowledge to know which of these categories is appropriate (obtained via experience, training, industry resources)

ST1.3 — General Process

The following process is most relevant for **Second Category** problems. However, it may still be used for First Category problems.

- **Step 1**. Postulate an analytical solution
  - consider the physical behavior, required testing to validate it, convenience, required accuracy and allowable conservatism, overall cost (development, testing, implementation, etc)
  - further discussion later
- **Step 2**. Evaluate the analytical solution with lower level testing (coupons, elements, details)
  - if results are acceptable, continue to the next step
  - if results are unacceptable:
    - adjust with semi-empirical correction factors/formulas ("minor" adjustments)

      –or–
    - if there are major discrepancies, consider going back to Step 1 and postulate a new analytical solution (initial test data is now available)

      –or–
    - if correlation is still poor after multiple attempts, consider a more test-based approach (more of a curve fit to test data)
  - at this point it is desirable to have a high confidence level in the method

ST1.3 — General Process (cont.)

- **Step 3**. Perform higher level testing (details, sub-components, components)
  - Evaluate the solution from Step 2
  - Primarily for validation and to expose unanticipated issues
  - Further adjust the solution if necessary (or go back to Step 1)
    - analysis and design changes at this level may be costly (attempt to avoid)
  - After completion, the result is a validated analysis method
    - "completion" means the method reliably predicts conservative results (and the absence of failure)
    - method is only valid within the given design space (do not extrapolate)
- **Step 4 (Optional Step)**. Implement the validated analysis method and further evaluate:
  - first: non-critical structures
  - next: critical structures (on a small scale)
  - next: critical structures (on a large scale)
  - Step 4 is an extra level of risk reduction (may not be necessary)

ST1.4 — Step 1: Further Discussion

Step 1 — Further Discussion: Most Relevant to **Second Category** problems

- Some factors to consider when postulating an analytical solution (consider all factors simultaneously)
  - Understand the analysis problem and limitations of classical solutions. This assists in forming the analytical solution and determining the type/quantity of testing required.
  - The analytical solution need not be "perfect" and probably won't capture the complete/actual physical behavior of the problem
    - The analytical solution may go up to the point where it is practical/useful. Going beyond this results in an overly complex, inappropriate, and misleading analytical solution.
    - In general, the more accurately the analytical solution captures the actual physical behavior, the less the required amount of testing.
  - There are a **variety** of acceptable analytical solutions
    - the goal is the best blend of analysis and testing for the specific circumstance
    - often be a unique "recipe"

ST1.4 — Step 1: Further Discussion

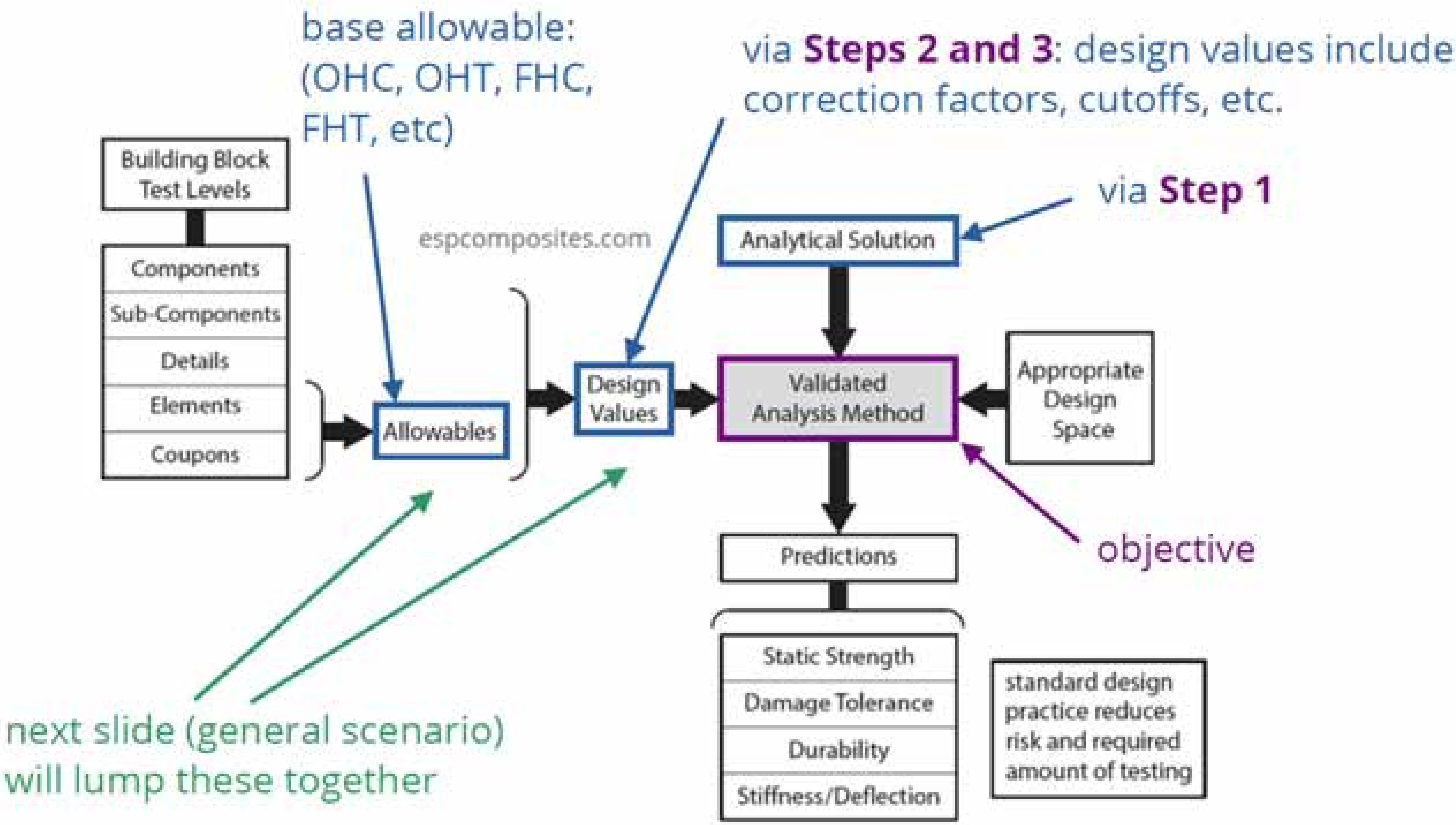
Step 1 — Further Discussion: Most Relevant to **Second Category** problems

- What is the required accuracy (and associated amount of conservatism) for the method?
  - high accuracy is not always required
  - conservative approaches require less testing (and associated lower cost)
  - conservative approaches may allow for simpler analytical solutions
- Determine the required amount/type of testing (affects analytical solution objectives)
  - what are the resource limitations?
- Analytical convenience
  - consider the practicality of implementing in an engineering environment
- **Overall cost** to develop and implement the validated analysis method
  - *predominant factor*
  - the engineering approach is to develop a validated analysis method, usually at the lowest overall cost
  - NOTE: academic focus is often to maximize analytical accuracy but less concern about viability of its use (or practical implementation) for real-world structures

engineering objectives and academic objectives may differ

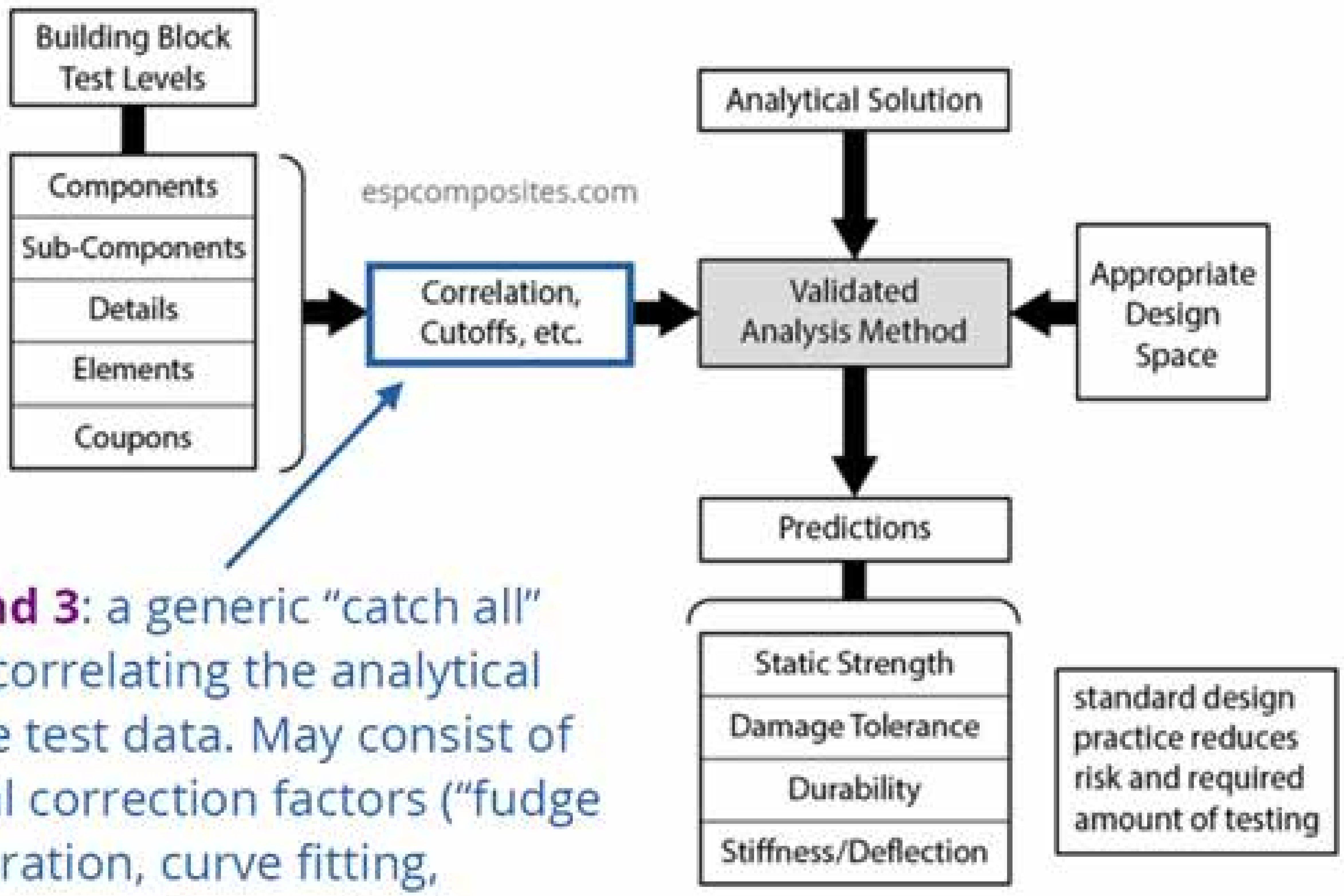
ST1.4 — Overview

- Flowchart more specific to strength analysis where a ***base allowable*** exists (figure also in Chapter 2): A common scenario for analysis of composites.



ST1.4 — Overview (cont.)

- ***General*** analysis problems (strength, deflection, stiffness, etc.): a base allowable may or may not exist



Via **Steps 2 and 3**: a generic "catch all" that includes correlating the analytical solution to the test data. May consist of semi-empirical correction factors ("fudge factors"), calibration, curve fitting, cutoffs, program requirements, etc.

ST1.5 — Basic Objectives

- Build general awareness of an engineering analysis approach (mostly related to Second Category problems)
  - Many metal solutions are First Category (carry over well from academic study).
  - However, some engineers may have limited exposure to the approach presented in this video (most relevant to Second Category problems). Developing semi-empirical methods is not usually taught in academia.
  - Composites tend to have more Second Category problems (don't carry over as well from academia)
  - Reduce confusion between engineering approaches and academic theory (may have different objectives)
    - industry objective may be to deliver a working product within a given cost and time
    - academic objective may be basic exposure for students or perform research
    - See also the free ST2 video (after viewing Chapter 10 if taking the course)
  - Demonstrates one way to address problems when classical solutions and academic theory alone is insufficient

ST1.5 — Basic Objectives (cont.)

- Remember, the analytical solution **need not** be physically accurate, physically consistent, or physically insightful, provided it is validated via test.
  - The method may even be a curve fit to test data with little "analytical" effort
- NOTE: Each company may have a different analysis method for the **same problem**
  - Method development is a function of many factors with a variety of acceptable solutions
- You may or may not have access to test data or the permissions to develop methods
  - Company provide you with a final method for you to implement
  - If development occurs in the "background", it may be difficult to reconcile the difference between the analytical solution and a pure solutions from academia. This video explains why that may occur.
  - Analyst may still **utilize/combine** the **basic methods** in a **specific way** for the given application
  - Regardless of your role, all stress analysts should be aware of proven industry approaches (as opposed to just academic theory)

ST1.6 — Notes

- Courses and book
  - demonstrate **practical methods and useful analytical solutions**
  - assist you in determining if your problem falls into the First Category or Second Category
  - intentionally do not provide complex analytical solutions that may not (or can not) translate to practical methods

End of Special Topic 1

Up Next

Chapter 3: Material Elasticity