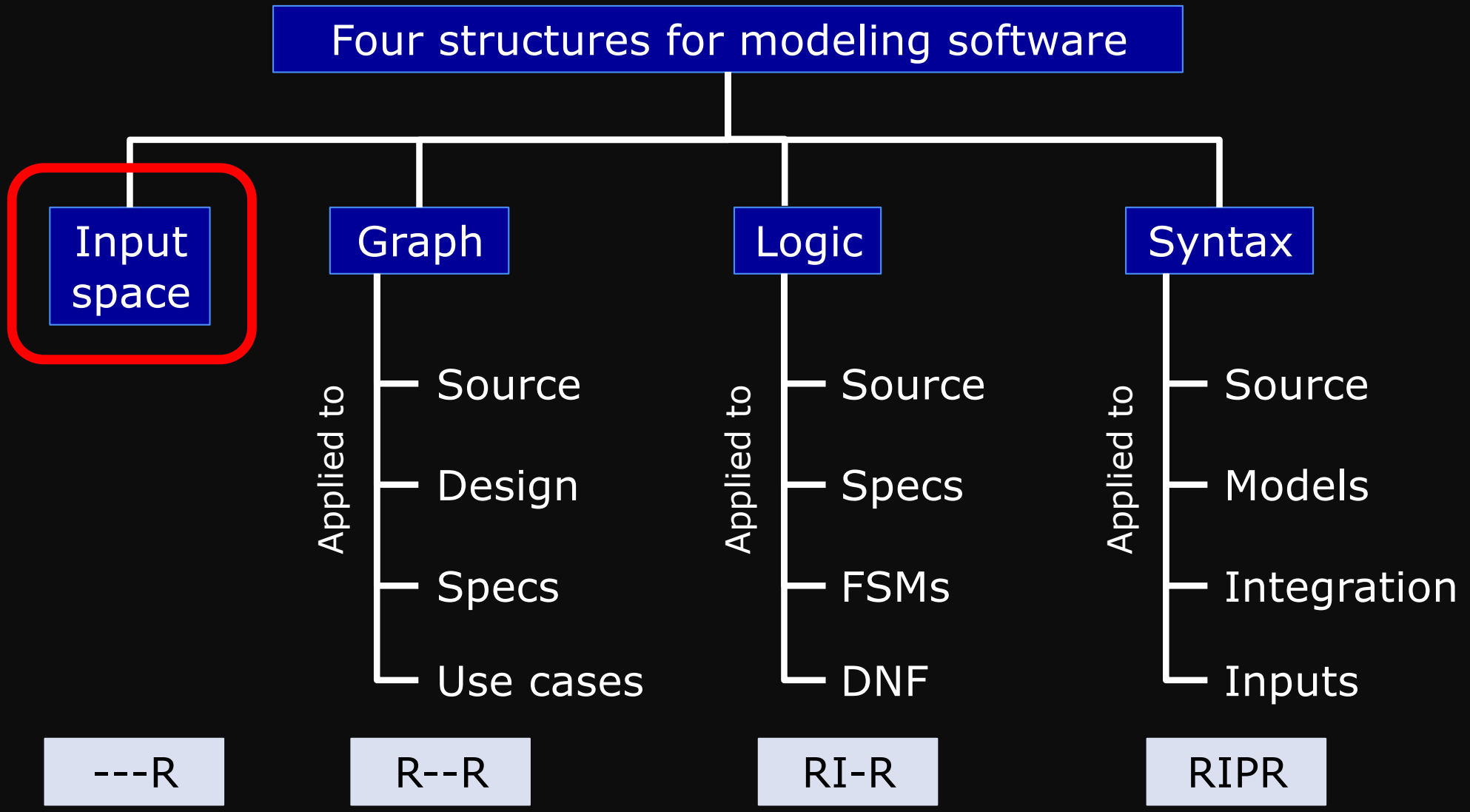
Input Space Partitioning Testing

CS 3250 Software Testing

[Ammann and Offutt, "Introduction to Software Testing," Ch. 6.1]

Structures for Criteria-Based Testing



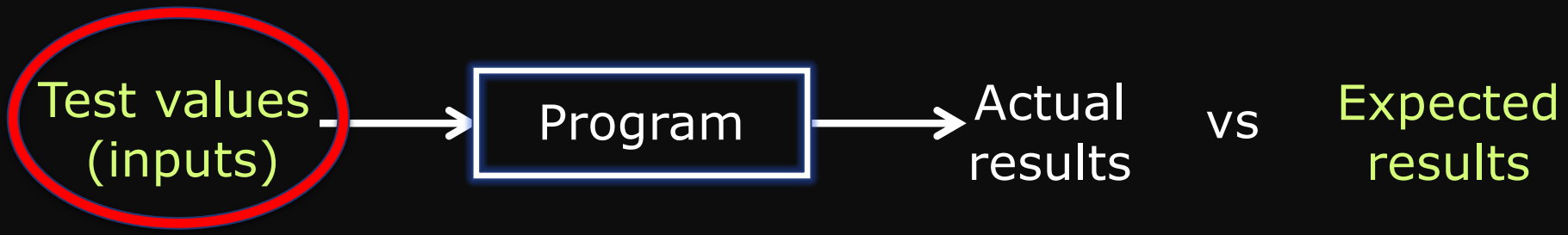
Today's Objectives

- Input domain (or input space)
- Fundamental of Input Space Partitioning (ISP)
  - Benefits of ISP
  - Partitioning input domain
  - Modeling input domain

Software Testing

- Testing = process of finding test input values to check against a software

Test case consists of test values and expected results



1. Testing is fundamentally about choosing finite sets of values from the input domain of the software being tested

2. Given the test inputs, compare the actual results with the expected results

Input Domains

- All possible values that the input parameters can have
- The input domain may be infinite even for a small program
- Testing is fundamentally about choosing finite sets of values from the input domain
- Input parameters can be
  - Parameters to a method (in unit testing)
  - Global variables (in unit testing)
  - Objects representing current state (in class or integration testing)
  - User level inputs (in system testing)
  - Data read from a file

Example Input Domains

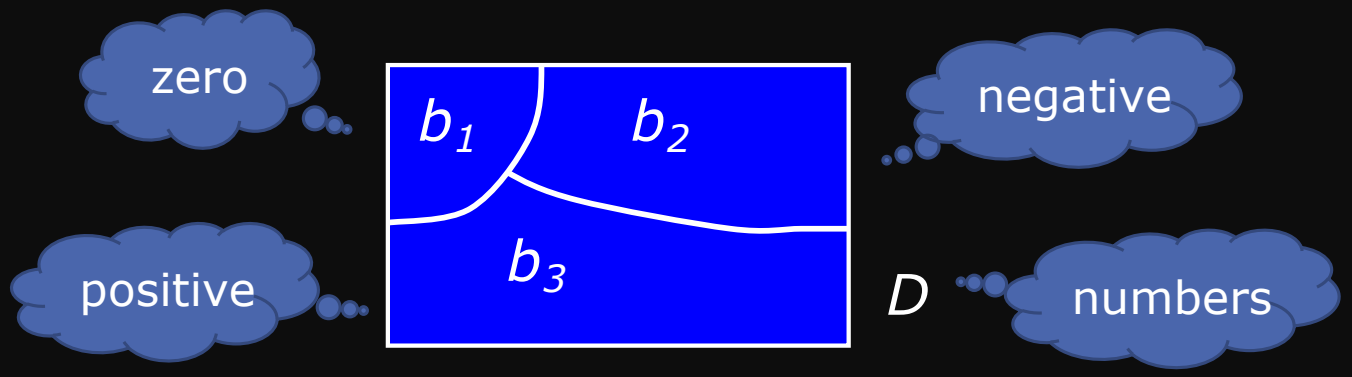
```
# Return index of the first occurrence of a letter in string,
# Otherwise, return -1

def get_index_of(string, letter):
    index = -1
    for i in range(1, len(string)):
        if string[i] == letter:
            return i
    return index
```

What is the domain of `string`?

What is the domain of `letter`?

Overview: ISP

- Input space partitioning describes the input domain of the software
- Domain (D) are partitioned into blocks (b_1, b_2, .., b_n)
- The partition (or blocks) must satisfy two properties
  - Blocks must not overlap (disjointness)
  - Blocks must cover the entire domain (completeness)

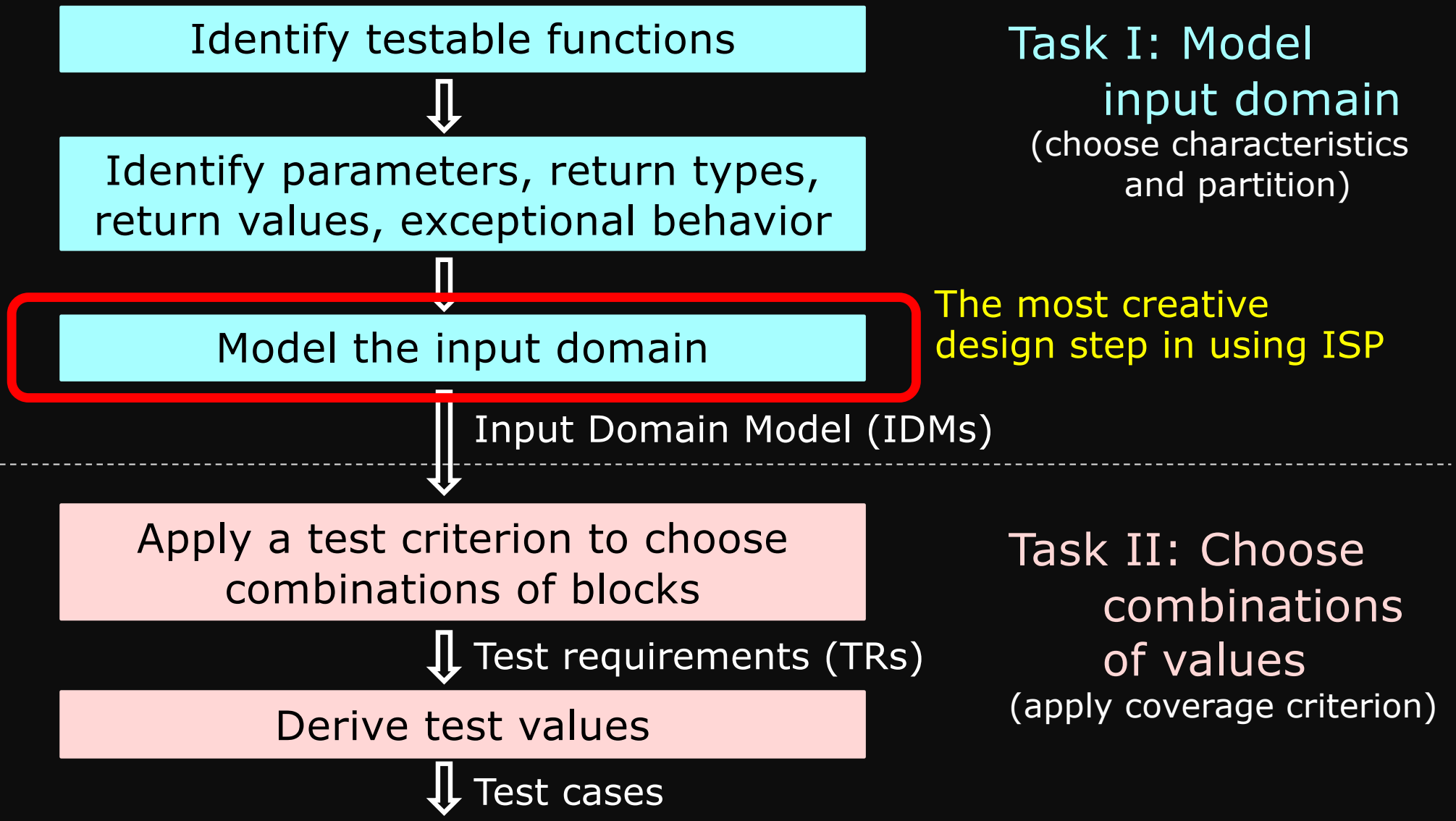


- At least one value is chosen from each block
  - Each value is assumed to be equally useful for testing

Benefits of ISP

- Easy to get started
  - Can be applied with no automation and very little training
- Easy to adjust to procedure to get more or fewer tests
- No implementation knowledge is needed
  - Just a description of the inputs
- Can be equally applied at several levels of testing
  - Unit (inputs from method parameters and non-local variables)
  - Integration (inputs from objects representing current state)
  - System (user-level inputs to a program)

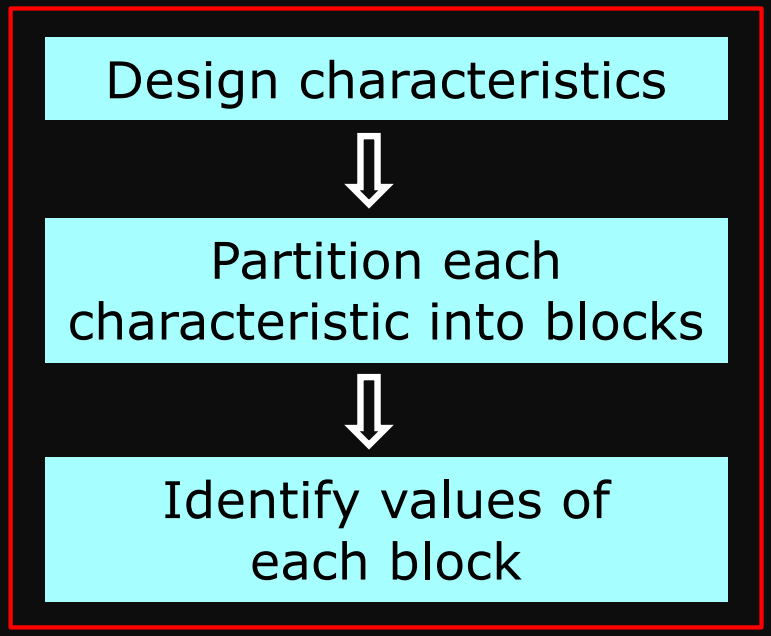
Applying ISP



Modeling the Input Domain

- The domain is scoped by the parameters
- Characteristics define the structure of the input domain
  - Should be based on the input domain – not program source

- Two Approaches
  - Interface-based (simpler)
    - Develop characteristics from individual parameters
  - Functionality-based (harder)
    - Develop characteristics from a behavior view



Design Characteristics

Interface-based

- Develop characteristics directly from parameters
  - Translate parameters to characteristics
- Consider each parameter separately
- Rely mostly on syntax
- Ignore some domain and semantic information
  - Can lead to an incomplete IDM
- Ignore relationships among parameters

Functionality-based

- Develop characteristics that correspond to the intended functionality
- Can use relationships among parameters, relationships of parameters with special values (null, blank, …), preconditions, and postconditions
- Incorporate domain and semantic knowledge
  - May lead to better tests
- The same parameter may appear in multiple characteristics

Partition Characteristics

Strategies for both approaches

- Partition is a set of blocks, designed using knowledge of what the software is supposed to do
- Each block represents a set of values
- More blocks means more tests
- Partition must satisfy disjointness and completeness properties

- Better to have more characteristics with few blocks
  - Fewer mistakes and fewer tests

How partitions should be identified and
how representative value should be selected from each block

Partitioning and Identifying Values

Strategies for both approaches

- Include valid, invalid and special values
- Sub-partition some blocks
- Explore boundaries of domains
- Include values that represent "normal use"
- Try to balance the number of blocks in each characteristic
- Check for completeness and disjointness

- Each value is assumed to be equally useful for testing

Interface-based Example1

```
# Return index of the first occurrence of a letter in string,
# Otherwise, return -1

def get_index_of(string, letter):
```

Task I: Model Input Domain

1. Identify testable functions
   - **`get_index_of()`**
2. Identify parameters, return types, return values, and exceptional behavior
   - Parameters: **`string`**, **`letter`**
   - Return type: **`int`**
   - Return value: index of the first occurrence, -1 if no occurrence
   - Exceptional behavior: **`??`**

Interface-based Example1 *(cont.)*

3. Model the input domain

- Develop characteristics
  - C1 = **`string`** is empty
  - C2 = **`letter`** is empty

What are other possible characteristics?

- Partition characteristics

Complete? Disjoint?

Characteristic	b1	b2
C1 = **string** is empty	True	False
C2 = **letter** is empty	True	False

- Identify (possible) values

Characteristic	b1	b2
C1 = **string** is empty	""	"testing"
C2 = **letter** is empty	""	"t"

Interface-based Example1 *(cont.)*

Task II: Choose combinations of values

4. Combine partitions to define test requirements
   - Assumption: choose all possible combinations
   - Test requirements -- number of tests (upper bound) = 2 * 2 = 4

     (True, True) (False, True)
     (True, False) (False, False)

   - Eliminate redundant tests and infeasible tests
5. Derive test values

Test	string	letter	Expected result
T1 (True, True)	""	""	-1
T2 (True, False)	""	"t"	-1
T3 (False, True)	"testing"	""	-1
T4 (False, False)	"testing"	"t"	0

Functionality-based Example1

```
# Return index of the first occurrence of a letter in string,
# Otherwise, return -1

def get_index_of(string, letter):
```

Task I: Model Input Domain

1. Identify testable functions
   - **`get_index_of()`**
2. Identify parameters, return types, return values, and exceptional behavior
   - Parameters: **`string`**, **`letter`**
   - Return type: **`int`**
   - Return value: index of the first occurrence, -1 if no occurrence
   - Exceptional behavior: **`??`**

Functionality-based Example1 *(cont.)*

3. Model the input domain

- Develop characteristics
  - C1 = number of occurrence of **`letter`** in **`string`**
  - C2 = **`letter`** occurs first in **`string`**

What are other possible characteristics?

- Partition characteristics

Complete? Disjoint?

Characteristic	b1	b2	b3
C1 = number of occurrence of **letter** in **string**	0	1	> 1
C2 = **letter** occurs first in **string**	True	False	

- Identify (possible) values

C	b1	b2	b3
C1	"software engineering", ""	"software engineering", "s"	"software engineering", "n"
C2	"software engineering", "s"	"software engineering", "t"	

Functionality-based Example1 *(cont.)*

Task II: Choose combinations of values

4. Combine partitions into tests
   - Assumption: choose all possible combinations
   - Test requirements -- number of tests (upper bound) = 3 * 2 = 6

(0, True)	(1, True)	(>1, True)
(0, False)	(1, False)	(>1, False)

   - Eliminate redundant tests and infeasible tests

5. Derive test values

Test	string	letter	Expected result
T1 (0, False)	"software engineering"	""	-1
T2 (1, True)	"software engineering"	"s"	0
T3 (1, False)	"software engineering"	"t"	3
T4 (>1, True)	"software testing"	"s"	0
T5 (>1, False)	"software engineering"	"n"	10

Interface-based Example2

```
public enum Triangle {Scalene, Isosceles, Equilateral, Invalid}
public static Triangle triang (int Side1, int Side2, int Side3)
# Side1, Side2, and Side3 represent the lengths of the sides of a
#    triangle.
# Return the appropriate enum value
```

Task I: Model Input Domain

1. Identify testable functions
   - **`triang()`**

2. Identify parameters, return types, return values, and exceptional behavior
   - Parameters: **`Side1`**, **`Side2`**, **`Side3`**
   - Return type: **`enum`**
   - Return value: **`enum`** describing type of a triangle
   - Exceptional behavior: **`??`**

Interface-based Example2 *(cont.)*

3. Model the input domain

- Develop characteristics
  - C1 = relation of **`Side1`** to 0
  - C2 = relation of **`Side2`** to 0
  - C3 = relation of **`Side3`** to 0

What are other possible characteristics?

- Partition characteristics

Complete? Disjoint?

Characteristic	b1	b2	b3
C1 = relation of **Side1** to 0	greater than 0	equal to 0	less than 0
C2 = relation of **Side2** to 0	greater than 0	equal to 0	less than 0
C3 = relation of **Side3** to 0	greater than 0	equal to 0	less than 0

- Identify (possible) values

Valid triangles?

Characteristic	b1	b2	b3
C1 = relation of **Side1** to 0	7	0	-3
C2 = relation of **Side2** to 0	3	0	-1
C3 = relation of **Side3** to 0	2	0	-2

Interface-based Example2 *(cont.)*

- Refine characteristics (can lead to more tests)
  - C1 = length of **`Side1`**
  - C2 = length of **`Side2`**
  - C3 = length of **`Side3`**

Refining characterization to get more fine-grained testing (if the budget allows)

- Partition characteristics

Complete? Disjoint?

Characteristic	b1	b2	b3	b4
C1 = length of **Side1**	greater than 1	equal to 1	equal to 0	less than 0
C2 = length of **Side2**	greater than 1	equal to 1	equal to 0	less than 0
C3 = length of **Side3**	greater than 1	equal to 1	equal to 0	less than 0

- Identify (possible) values

Valid triangles?

Characteristic	b1	b2	b3	b4
C1 = length of **Side1**	2	1	0	-1
C2 = length of **Side2**	2	1	0	-1
C3 = length of **Side3**	2	1	0	-1

Boundary tests

Interface-based Example2 *(cont.)*

Task II: Choose combinations of values

4. Combine partitions to define test requirements
   - Assumption: choose all possible combinations
   - Test requirements -- number of tests (upper bound) = 4*4*4 = 64

     (C1b1, C2b1, C3b1) (C1b1, C2b2, C3b1) (C1b1, C2b3, C3b1) (C1b1, C2b4, C3b1)
     (C1b1, C2b1, C3b2) (C1b1, C2b2, C3b2) (C1b1, C2b3, C3b2) (C1b1, C2b4, C3b2)
     (C1b1, C2b1, C3b3) (C1b1, C2b2, C3b3) (C1b1, C2b3, C3b3) (C1b1, C2b4, C3b3)
     (C1b1, C2b1, C3b4) (C1b1, C2b2, C3b4) (C1b1, C2b3, C3b4) (C1b1, C2b4, C3b4)
     (C1b2, C2b1, C3b4) (C1b2, C2b2, C3b4) (C1b2, C2b3, C3b4) (C1b2, C2b4, C3b4)
     …

     Do we really need these many tests?

   - Eliminate redundant tests and infeasible tests
5. Derive test values

   (2, 2, 2) (2, 1, 2) (2, 0, 2) (2, -1, 2)
   (2, 2, 1) (2, 1, 1) (2, 0, 1) (2, -1, 1)
   …

Functionality-based Example2

```
public enum Triangle {Scalene, Isosceles, Equilateral, Invalid}
public static Triangle triang (int Side1, int Side2, int Side3)
# Side1, Side2, and Side3 represent the lengths of the sides of a
#    triangle.
# Return the appropriate enum value
```

Task I: Model Input Domain

1. Identify testable functions
   - **`triang()`**

2. Identify parameters, return types, return values, and exceptional behavior
   - Parameters: **`Side1`**, **`Side2`**, **`Side3`**
   - Return type: **`enum`**
   - Return value: enum describing type of a triangle
   - Exceptional behavior: **`??`**

Functionality-based Example2 *(cont.)*

3. Model the input domain

- Develop characteristics
  - C1 =Geometric classification

What are other possible characteristics?

- Partition characteristics

Complete? Disjoint?

Characteristic	b1	b2	b3	b4
C1 = Geometric classification	scalene	isosceles	equilateral	invalid

- Refine characteristics

Complete? Disjoint?

Characteristic	b1	b2	b3	b4
C1 = Geometric classification	scalene	Isosceles, not equilateral	equilateral	invalid

- Identify (possible) values

Characteristic	b1	b2	b3	b4
C1 = Geometric classification	(4, 5, 6)	(3, 3, 4)	(3, 3, 3)	(3, 4, 8)

Functionality-based Example2 *(cont.)*

Task II: Choose combinations of values

4. Combine partitions into tests
   - Assumption: choose all possible combinations
   - Test requirements -- number of tests (upper bound) = 4

     (C1b1) (C1b2) (C1b3) (C1b4)
   - Eliminate redundant tests and infeasible tests

5. Derive test values

Test	Side1	Side2	Side3	Expected result
T1 (scalene)	4	5	6	scalene
T2 (isosceles, not equilateral)	3	3	4	isosceles
T3 (equilateral)	3	3	3	equilateral
T4 (invalid)	3	4	8	invalid

This characteristic results in a simple set of test requirements.
Is this good enough?
If we define the characteristics differently? Multiple IDMs?

ISP Task I Summary

- Easy to apply, even with no automation and little training
- Easy to add more or fewer tests
- Rely on the input space, not implementation knowledge
- Applicable to all levels of testing, effective and widely used

Interface-based approach

Strength

- Easy to identify characteristics
- Easy to translate abstract tests into executable test cases

Weakness

- Some information will not be used – lead to incomplete IDM
- Ignore relationships among parameters

Functionality-based approach

Strength

- Incorporate semantic
- Input domain modeling and test case generation in early development phases

Weakness

- Difficult to design reasonable characteristics
- Hard to generate tests

What's Next?

- How should we consider multiple partitions or IDMs at the same time?
- What combinations of blocks should we choose values from?
- How many tests should we expect?